Human Health Risk Assessment

for the

Standley Lake Diversion Project

Prepared for

City of Westminster
City of Northglenn
City of Thornton

Prepared by

CH2M HILL

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Acronyms

BEIR	Biological Effects of Ionizing Radiation
bls	below land surface
CDH	Colorado Department of Health
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
CNS	central nervous system
CRQL	contract required quantitation limit
CSM	conceptual site model
DCF	dose conversion factor
DNA	deoxyribonucleic acid
DOE	Department of Energy
ELCR	excess lifetime cancer risk
EPA	Environmental Protection Agency
FDM	Fugitive Dust Model
FSP	Field Sampling Plan
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
ICRU	International Commission on Radiation Units and Measurements
IDL	Instrument Detection Limit
IRIS	Integrated Risk Information System
LET	linear energy transfer
LOAEL	lowest observed adverse effect level
MDA	minimum detectable activity
MeV	million electron volt
MS	matrix spike
NCRP	National Council on Radiation Protection and Measurements
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NOAEL	no observed adverse effect level
ORNL	Oak Ridge National Laboratory
OSWER	Office of Solid Waste and Emergency Response
ppm	parts per million
QAPP	Quality Assurance Project Plan
QC	quality control
QL	quantitation limit
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RFP	Rocky Flats Plant
RPD	Relative Percent Difference
SF	slope factor

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Acronyms
(continued)

SLDP	Standley Lake Diversion Project
TAL	Target Analyte List
TCL	Target Compound List
TM	technical memorandum
TSP	total suspended particulates
UCL	upper confidence limit
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WCR	Woman Creek Reservoir
WL	working level
WLM	working-level month

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Executive Summary

This risk assessment presents risks of exposure to chemical and radiological contaminants in soil and sediments during construction of the SLDP. Risks are summarized for construction worker, construction "hot spot," residential, and future recreational exposure scenarios via incidental ingestion of soils, inhalation of contaminants in suspended dust, and direct gamma exposure. In addition, qualitative evaluations are shown for future exposures to radiological contaminants suspended and redeposited during construction activities, and radiological risks for exposures to children.

A summary of risks associated with exposure to contaminants during construction of the SLDP under each scenario is shown in Table ES-1.

Of the scenarios evaluated, the worker and residential exposure pathways were the only pathways which showed risks greater than 1×10^{-6}. In general, risks associated with radiological contaminants were greater than risks associated with chemical contaminants. For the construction worker, the upper bound radiological risk is 3×10^{-6}. Most of this risk is associated with inhalation of dusts containing background concentrations of naturally occurring uranium. The evaluation of chemical contaminants showed construction worker risks less than 10^{-6} and HIs less than 1.0 for upper bound conditions.

For nearby residents, radiological risks are 2×10^{-6} under upper bound exposure conditions. As with construction workers, most of the residential risk is associated with inhalation of dusts containing background concentrations of naturally occurring uranium. For chemicals, risk of cancer incidence was less than 1×10^{-6}, and HIs were less than 1.0 under the upper bound residential exposure scenario. A qualitative evaluation of radiological exposures to children showed risks similar to the residential exposure scenario (approximately 3×10^{-6}).

In general, risks associated with exposure to contaminants in soil and sediments during construction of the SLDP are minimal. The EPA uses a risk range of 10^{-4} to 10^{-6} for the purpose of making remedial action decisions on Superfund sites. The maximum incremental risk of cancer incidence calculated in this assessment is 3×10^{-6} (constructor worker scenario, child radiological evaluation).

This risk is at the low end of the range that EPA uses for decision making, and represents an increased chance of cancer incidence of 3 cancers in a population of 1 million persons. This risk is both small in comparison to the EPA's risk range of concern ($10^{-4} - 10^{-6}$), and the current U.S. average lifetime risk of developing cancer (approximately 0.2, or 1 cancer per 5 individuals).

Table ES-1
Summary of Risks Associated with Exposure to Contaminants During Construction of the SLDP

Scenario	Total Chemical Risks				Total Radiological Risks	
	Average Exposure		Upper Bound Exposure			
	Excess Cancer Risk	Hazard Index	Excess Cancer Risk	Hazard Index	Average Exposure	Upper Bound Exposure
Construction Worker	2×10^{-7}	0.28	3×10^{-7}	0.53	2×10^{-6}	3×10^{-6}
Construction "Hot Spot"	NA	NA	NA	0.01	NA	2×10^{-8}
Residential	1×10^{-7}	0.14	2×10^{-7}	0.26	1×10^{-6} $(2 \times 10^{-6})^{a}$	2×10^{-6} $(3 \times 10^{-6})^{a}$
Recreational	NA	NA	NA	0.005	NA	3×10^{-7}

[a]Upper bound qualitative risk estimate for child exposure to radioactive contaminants.

Note:

NA = Not Applicable

Section 1
Introduction

This draft human health risk assessment was prepared to evaluate the potential risks and associated exposure to contaminants in soil or sediment during construction of the Standley Lake Diversion Project (SLDP). The SLDP has been proposed as a mechanism to protect Standley Lake from runoff and potential releases of contaminated surface water from the Rocky Flats Plant (RFP). The area southeast of the RFP, through which the diversion project will traverse, has been shown to contain slightly elevated concentrations of radionuclides as a result of past RFP airborne releases. This risk assessment will be used to determine if construction activities in this area present significant human health risks from exposure to contaminants in disturbed soils or sediments.

This assessment generally follows Environmental Protection Agency (EPA) guidance from *Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual, Part A* (EPA, 1989a). The assessment consists of the following major elements:

- Data Evaluation (Section 2)
- Toxicity Assessment (Section 3)
- Exposure Assessment (Section 4)
- Risk Characterization (Section 5)
- Evaluation of Uncertainty (Section 6)
- Summary and Conclusions (Section 7)

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1.1 Background

Standley Lake is a large water supply reservoir used by the cities of Westminster, Thornton, and Northglenn, Colorado (the Cities). It is located in the northwest quadrant of the Denver Metropolitan region, southeast of the Department of Energy's (DOE's) RFP, a nuclear weapons components manufacturing plant. The major source of water in Standley Lake is snowmelt from the Rocky Mountains that flows via Clear Creek. Stream flows are diverted from Clear Creek near Golden, Colorado, and delivered to Standley Lake through a series of interceptor ditches and other drainages and creeks. Water also enters at the west end of Standley Lake through Upper Big Dry Creek and Woman Creek. Woman Creek flows just south of the main RFP area. Figure 1-1 shows the location of Standley Lake, the SLDP area, and the RFP.

Accidental and incidental releases of radionuclides and metals from the RFP have occurred during 40 years of operations. As a result, higher than background levels of some radionuclides specific to the RFP operations have been detected in the soils and sediments surrounding the plant and Standley Lake (CH2M HILL, 1992). Because of the downgradient location of Standley Lake, a potential exists for precipitation-induced runoff of contaminated soils to reach Standley Lake, resulting in a degradation of the water quality. Also, since Woman Creek is directly south of the main plant area, accidental releases of high levels of contaminants from the RFP could directly affect Standley Lake. The Cities, together with DOE, EPA, and the Colorado Department of Health (CDH), have developed a protection plan for the Standley Lake water supply, called the Standley Lake Protection Project (SLPP). This project includes construction of a series of surface water management facilities to physically isolate Standley Lake from runoff originating on the RFP. The SLPP includes construction of Woman Creek Reservoir (WCR) (an upstream catchment pond), a diversion canal around Standley Lake, pipelines and a pumping station. WCR and the diversion canal, collectively known as the SLDP are to be constructed first to provide initial physical isolation for Standley Lake.

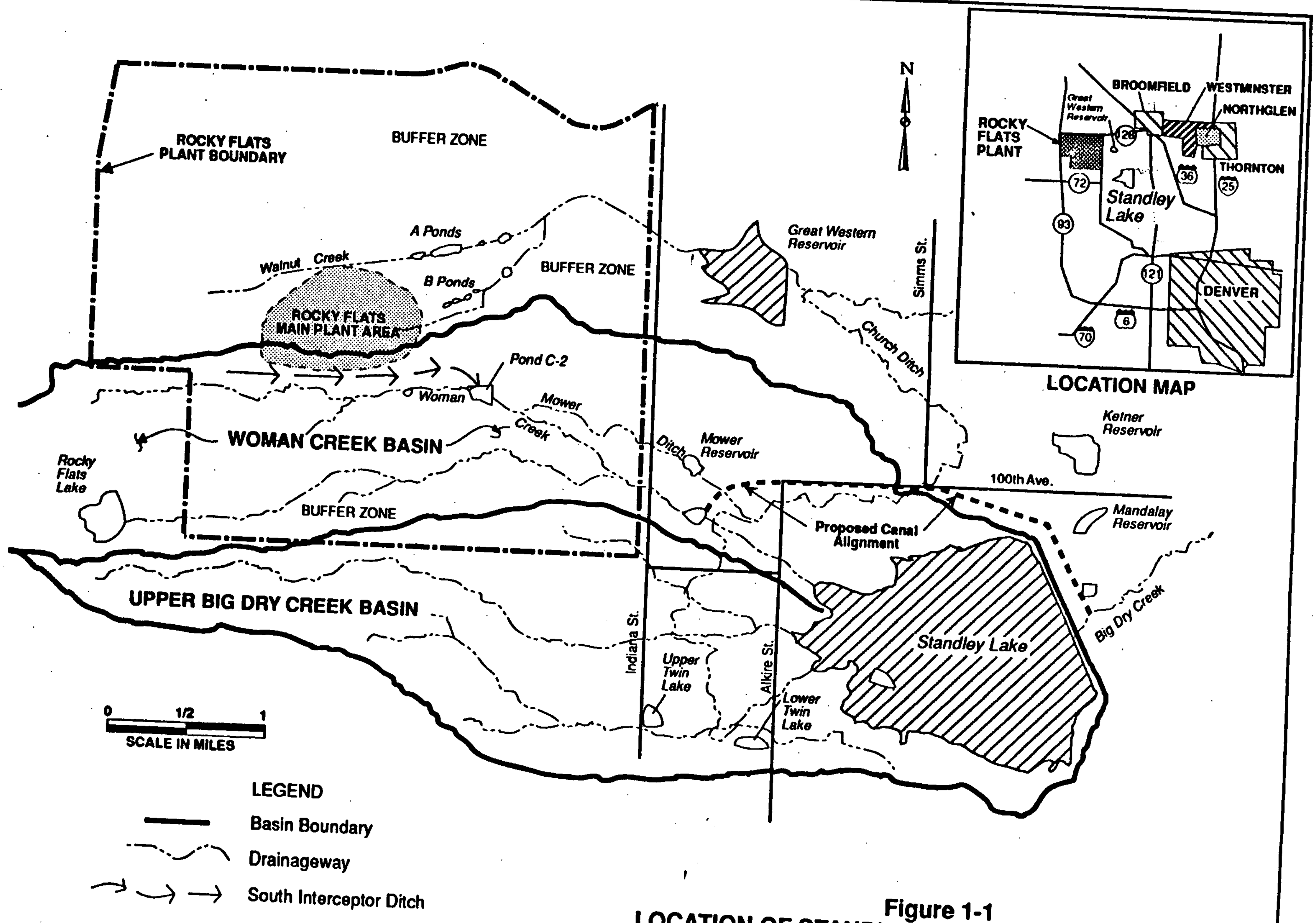

Figure 1-1
LOCATION OF STANDLEY LAKE, THE PROJECT AREA, AND THE ROCKY FLATS PLANT

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A detailed description of the SLDP, land use, and natural resources may be found in the Draft Environmental Assessment for the Standley Lake Diversion Project (DOE, 1992). The proposed diversion alignment for the SLDP is shown in Figure 1-1.

Prior to construction of the SLDP, a quantitative risk assessment is necessary for estimating the potential risks under specific exposure scenarios to assess whether construction workers and nearby residents could be subject to health risks arising from exposures to potential contaminants in the soils as a result of disruption during construction (CH2M HILL, 1992). Soil and sediment samples were collected to evaluate the presence of contaminants in the construction area of the SLDP. Also, fugitive dust concentrations from different types of construction activities, such as excavation stockpiling, hauling, and backfilling, were modeled for use in estimating intake to the receptors via inhalation. The results from the soil and sediment sampling and from the fugitive dust modeling are used in this assessment to calculate estimates of risk under construction and residential exposure conditions.

1.2 Purpose and Objective

The primary purpose of the human health risk assessment was to assess incremental risks associated with exposures to potentially contaminated soils that may be disturbed during construction of the SLDP. The objective of the quantitative risk assessment is to estimate whether construction workers or nearby residents will be exposed to unacceptable levels of potential contaminants in the soils and sediments disturbed during the construction activities. Information derived from this evaluation will be used in making risk management decisions concerning the construction of the SLDP.

This risk assessment generally follows guidelines set forth by EPA for conducting risk assessments under CERCLA. However, this assessment is not a full baseline risk assessment because total site risks were not evaluated. Only the potential risks caused by construction of the SLDP are addressed in this assessment. Therefore exposure scenarios were limited to those most likely to occur as a result of construction activities rather than assessing total site risks under a no-action scenario. An ecological risk assessment was not performed because construction activities are not expected to cause increased exposures to aquatic and terrestrial organisms (greater than current exposures to existing contaminants). It is likely that construction activities will keep terrestrial organisms away from the area, and thus potential for exposure to contaminated dusts will be minimal.

Section 2

Data Evaluation

2.1 Background and Summary

An evaluation of the analytical data from the samples collected from the six areas within the diversion project construction zone was completed to assess the usability of the data for this quantitative risk assessment. Samples consisted of surface soil composite samples, soil boring discrete samples from an interval between zero and 6 in. below land surface (bls), soil boring composite samples collected up to 30 ft bls, and sediment composite samples collected along transects across selected stream locations. Also, corresponding field and laboratory blanks as described in the Field Sampling, Analysis, and Quality Assurance Project Plan (QAPP) for the SLDP (CH2M HILL, 1992) were evaluated. Constituents analysis included the Target Analyte List (TAL) suite of metals, cyanide, the triazine pesticides and simazine, and an array of radionuclides related to the RFP (see Table 2-1). Sampling procedures for these constituents are described in the above-referenced project plan (CH2M HILL, 1992).

Analytical methods followed were equivalent to EPA's Contract Laboratory Program (CLP) methods (for nonradiological constituents) and those referenced in the EG&G GRRASP (EG&G, 1991) for radiological constituents. A detailed discussion of the analytical results in terms of the nature and extent of contamination was not within the scope of this risk assessment. However, the data were used to assess the potential risks associated with disruption of surface and subsurface soils as a result of the planned construction of the diversion project. Below is a discussion of the procedures used to evaluate the nonradiological and radiological analytical data prior to its use for the quantitative risk assessment.

Table 2-1 Chemical Analytes Standley Lake Diversion Project	
Target Analyte List (TAL) Metals	
Antimony	Manganese
Arsenic	Mercury
Barium	Nickel
Beryllium	Selenium
Cadmium	Thallium
Copper	Vanadium
Chromium	Zinc
Lead	
Other Inorganics	
Cyanide	
Organic Pesticides	
Atrazine	Simazine
Radionuclides	
Pu-239	Am-241
U-234	Gross Alpha
U-235	Gross Beta
U-238	

The nonradiological data evaluation included review of quantitation limits, blank sample results, laboratory qualifiers and codes, and detected concentrations versus published regional background concentrations. This evaluation revealed no data points that were considered unacceptable for use in a human health risk assessment.

The radiological data evaluation included review of laboratory procedures; review of laboratory and field quality control (QC) samples; review of laboratory data sheets, including checks of calculations and data transcription; review of raw count data, including radiochemical recoveries, counting efficiency, and counting error; evaluation of minimum detectable activity (MDA) levels; and comparison to published regional background concentrations. Guidance used for the data evaluation included EPA's *Risk Assessment Guidance For Superfund, Volume 1, Human Health Evaluation Manual, Part A (RAGS), Guidance for Data Useability in Risk Assessment (Part B)*, and internal CH2M HILL radiological data evaluation and validation protocols.

Evaluation of the radiological data revealed no data points that were considered unacceptable for use in a human health assessment. In general, the laboratory followed established radiological procedures and produced results of known quality. Some of the results would be considered "estimated" under rigorous data validation procedures, but none of the data points would have been rejected. A more detailed discussion of the results of the data evaluation for nonradiological and radiological constituents is provided in the following sections.

2.2 Nonradiological Constituents

2.2.1 Evaluation of Quantitation Limits

The quantitation limits (QLs) reported by the laboratory were compared to risk-based soil reference concentrations in order to evaluate the appropriateness of the QLs reported. As stated previously, samples were analyzed under the CLP protocol; therefore, the QLs are

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referred to as contract required quantitation limits (CRQLs). These chemical-specific values are the lowest levels at which a chemical may be accurately and reproducibly quantitated for a given sample matrix. Generally, CRQLs were reported below risk-based reference concentrations so that constituent concentrations reported below the CRQL (i.e., estimated concentration identified by a U qualifier) would not exceed levels of potential concern in a quantitative risk assessment.

Of the nonradiological compounds analyzed for in soil and sediment and listed in Table 2-1, only beryllium and cadmium had CRQLs that potentially exceeded risk-based soil reference concentrations. The CRQL for beryllium (1.0 mg/kg) exceeded the soil reference concentrations derived for soil ingestion (0.16 mg/kg) and inhalation (0.084 mg/kg) of contaminated particulates based on carcinogenic effects, while that for cadmium (1.0 mg/kg) exceeded the soil reference concentration for inhalation (0.11 mg/kg) of contaminated particulates based only on carcinogenic effects. The soil reference concentrations for inhalation of contaminated particulates assumes a dust concentration of 5 $\mu g/m^3$. However, risk-based reference concentrations were derived from chronic exposures to chemicals for approximately 30 years, while the exposures included in this risk assessment were assumed to occur primarily during the construction duration (approximately one year).

2.2.2 Evaluation of Blank Samples

Analytical results reported for blank samples were evaluated to assess the potential for contamination introduced into sample sets in the field during sample collection or in the laboratory during sample preparation or analysis. None of the blank samples contained detectable concentrations of the inorganic constituents or pesticides listed in Table 2-1. Blank analytical data for these constituents, including both soil and water matrices, were analyzed for but not detected (i.e., data flagged with U qualifiers).

2.2.3 Evaluation of Qualifiers and Laboratory Codes

The CLP analytical results received by the laboratory consisted of qualifiers and codes where appropriate. These data were flagged by the laboratory to indicate potential problems or questions concerning chemical concentrations or limitations in analytical methods used. Qualified data were evaluated before use in the quantitative risk assessment. Table 2-2 lists the qualifiers attached to the data received by the laboratory.

None of the flagged data were rejected on the basis of attached laboratory qualifiers or codes. The results for several analytes were flagged with qualifiers listed in Table 2-2. Data flagged by a qualifier B or U do not indicate data quality problems; therefore these data may be used in a quantitative risk assessment. Data flagged by a qualifier N or * indicate potential data quality questions. These data may also be used in a quantitative risk assessment. Uncertainties associated with the use of these flagged data are discussed in the uncertainties section (Section 6).

2.2.4 Comparison of Detected Concentrations with Published Regional Background Data

Field sample results were compared to regional background metals concentrations in Colorado soils from the literature to assess whether or not trends exist in the reported data from samples within the SLDP construction corridor. Background literature values were used as a basis for initial comparison to identify metals that may exceed background ranges. These background values represent statewide variations and may not depict site-specific concentrations. Analytical results for TAL metals fell within the ranges established in the literature. Arithmetic mean values of constituents that exceeded their respective literature mean values included manganese in composite sediment samples and nickel in shallow soil boring discrete samples and in soil boring composite samples.

Table 2-2 Laboratory Qualifiers Attached to Sample Results Standley Lake Diversion Project	
Qualifier	**Description**
Concentration Qualifiers (C)	
B	Reported value was obtained from a reading that was less than the CRQL, but was greater than or equal to the Instrument Detection Limit (IDL).
U	Analyte was analyzed for but not detected.
Quality Qualifiers (Q)	
N	Spiked sample recovery not within control limits.
*	Duplicate analysis not within control limits.
Source: International Technology Analytical Services, Oak Ridge, Tennessee.	

2.3 Radiological Constituents

2.3.1 Duplicate Samples

A summary of duplicate sample results is shown in Table 2-3. This summary includes a comparison of the Relative Percent Difference (RPD) between the original sample and both the laboratory duplicate and the field duplicate of the original sample. For radiological samples, an RPD control limit of ±35 percent is commonly used for soil samples with activity concentrations greater than 5 times the sample MDA. When the sample activity is less than 5 times the MDA, results are considered acceptable when the sample concentration falls within the range of the duplicate concentration ±2 times the MDA concentration.

The duplicate results for gross alpha, gross beta, U-233/234, U-235/236, and U-238 fell within the control criteria shown above. The results for Pu-239/240 fell outside of these control criteria, but in most instances, this was caused by the very low detect values. For example, a result of 0.253 pCi/g Pu-239 was not significantly different from 0.164 pCi/g, yet this result showed an RPD of 42.7 percent. In general, the Pu-239 duplicate results indicated that the Pu-239 environmental sample results were of acceptable quality, given the variability of sample media and the sensitivity of low-level alpha counting.

The duplicate results for Am-241 showed characteristics similar to the Pu-239 results, with the exception of sample number SD1. The original sample result for SD1 showed 0.62 pCi/g Am-241, while the duplicate showed only 0.0469 pCi/g Am-241. A review of the raw data for SD1 showed that the calculated results appear accurate. The high concentration possibly was the result of contamination of this sample, or the variation between the two concentrations possibly was a result of media interferences. The 0.62 pCi/g result was carried through to the risk assessment as a conservative estimate of Am-241 activity.

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Table 2-3
Duplicate Results Summary

Sample Number	Sample Result (pCi/g)	Lab Duplicate (pCi/g)	RPD[a] (Original Sample to Lab Duplicate)	Field Duplicate (pCi/g)	RPD[a] (Original Sample to Field Duplicate)
Parameter: Gross Alpha					
SB1-0.5	22.6	21.4	5.45	23.0	1.75
SB1-COMP	12.6			13.4	6.15
SB5-0.5	24.5	29.3			
SD1	21.8	16.7	26.40	17.0	24.74
SL1-COMP	35.5			31.6	11.62
Parameter: Gross Beta					
SB1-0.5	24.1	28.7	17.42	25.0	3.76
SB1-COMP	15.5			15.9	2.54
SB5-0.5	30.4	33.0			
SD1	16.2	17.6	8.28	21.2	26.74
SD1-COMP	31.8			33.3	4.61
Parameter: Am-241					
SB1-0.5	0.0426	0.0354	18.46	0.074	53.86
SB1-COMP	0.0111			0.00512	73.74
SD1	0.62			0.0469	171.87
SL1-COMP	0.0894			0.0876	2.03
Parameter: Pu-239/240					
SB1-0.5	0.253	0.164	42.69	0.65	87.93
SB1-COMP	0.0408			0.00846	131.3
SD1	0.127			0.206	47.48
SL1-COMP	0.453			0.718	45.26
Parameter: U-233/234					
SB1-0.5	1.0	0.898	10.75	0.908	9.64
SB1-COMP	0.74			0.723	2.32

Table 2-3
Duplicate Results Summary

Sample Number	Sample Result (pCi/g)	Lab Duplicate (pCi/g)	RPD[a] (Original Sample to Lab Duplicate)	Field Duplicate (pCi/g)	RPD[a] (Original Sample to Field Duplicate)
Parameter: U-233/234 (continued)					
SD1	1.49			1.46	2.03
SL1-COMP	1.41			1.09	25.60
Parameter: U-235/236					
SB1-0.5	<0.067	<0.054	NA	<0.12	NA
SB1-COMP	<0.052			<0.045	NA
SD1	<0.087			0.0662	NA
SL1-COMP	0.192			0.0512	<±2 × MDA
Parameter: U-238					
SB1-0.5	0.896	1.02	12.94	1.25	32.99
SB1-COMP	0.659			0.688	4.31
SD1	1.08			1.13	4.53
SL1-COMP	1.14			0.973	15.81

[a]RPD is defined as:

$$\frac{|S - D|}{(S + D)/2} \times 100$$

where

S = original sample result
D = duplicate sample result

Notes:

NA = Not Applicable.
<±2 × MDA = Sample result falls within the range of the duplicate ±2× the duplicate MDA level. This test is used for samples with activity concentrations less than 5× the MDA. For these low activity samples, the RPD test is not appropriate since the results are very close to background levels.

2.3.2 Blank Samples

Laboratory blank results are shown in Table 2-4. These blank results fall within the ranges expected for gross alpha, gross beta, Am-241, Pu-239/240, and U-238 analyses. The blank results provide good evidence that laboratory contamination or improper background subtraction were not generally a problem with the SLDP samples.

2.3.3 Spike Samples

A summary of matrix spike (MS) results is shown in Table 2-5. In general, these results show acceptable agreement between the amount of activity added (spiked) and the MS result.

2.3.4 Raw Data Review

Ten percent of the sample set was selected for calculation verification. Detector efficiencies were not consistently supplied in the raw data, but were obtained from the laboratory on request. Sample activity calculations were verified as accurate in the selected data set. A summary of radiochemical recovery values for plutonium, americium, and uranium is shown in Table 2-6. For the selected data set, recoveries ranged from 41.30 to 80.60 percent, which is an acceptable recovery range for these radionuclides.

2.4 Contaminants of Concern

Contaminants of concern are chemicals that are detected and subsequently selected from an initial list of site-related chemicals based on the quality of their reported data (EPA, 1989a). The selection of contaminants of concern followed an evaluation of the data as previously described. These are the chemicals that were carried through the quantitative risk assessment. Below are discussions of the nonradiological and radiological contaminants of potential concern.

Table 2-4 Blank Results Summary		
Sample Number	Result	Test Units
Parameter: Gross Alpha		
S20905918	-0.11	DPM/SA
S20901219	0	DPM/SA
S20901305	0.76	DPM/SA
S20906005	1.19	DPM/SA
Parameter: Gross Beta		
S20905918	0.08	DPM/SA
S20906005	0.11	DPM/SA
S20901219	0.06	DPM/SA
S20901305	-0.02	DPM/SA
Parameter: Am-241		
S20906005	0.05	DPM/SA
S20905918	0.08	DPM/SA
S20901305	0.2	DPM/SA
S20901219	0.08	DPM/SA
Parameter: Pu-239/240		
S20905918	0.01	DPM/SA
S20906005	0.11	DPM/SA
S20901305	0.03	DPM/SA
S20901219	0.1	DPM/SA
Parameter: U-238		
S20901219	0.07	DPM/SA
S20906005	0.23	DPM/SA
S20901305	0.18	DPM/SA
S20905918	0.25	DPM/SA

Table 2-5
Matrix Spike Results Summary

Sample Number	Spike Added (DPM)	MS Result (DPM)	Percent Difference[a]
Parameter: Gross Alpha			
MS SB1R-COMP	24.18	29.86	23.5
MS SL1R-COMP	24.18	17.5	27.6
Parameter: Gross Beta			
MS SB1R-COMP	101.67	106.46	4.7
MS SL1R-COMP	101.79	103.75	2.1
Parameter: Am-241			
MS SB2-0.5	2.02	1.33	34.2
MS SB1R-COMP	2.02	1.72	14.9
MS SL1R-COMP	2.02	2.80	38.6
Parameter: Pu-Iso			
MS SB2-0.5	4.03	4.39	8.9
MS SB1R-COMP	4.03	4.1	1.7
MS SL1R-COMP	4.03	4.09	1.5
Parameter: U-Iso			
MS SB1R-COMP	24.1	24.35	1.0
MS SL1R-COMP	48.2	54.4	12.9

[a]Percent Difference =

$$\frac{|Spike\ Added - MS\ Result|}{Spike\ Added}$$

Table 2-6
Radiochemical Recovery
(Percent Yield)

Sample Number	Pu	Am	U
SD1R (Aqueous)	77.57	68.61	67.80
SB3-0.5 (Soil)	57.29	77.06	NA
SB6-COMP (Soil)	58.21	74.23	42.25
SD4 (Sediment)	67.57	73.18	55.83
SB1R-COMP (Aqueous)	73.02	80.60	41.30
SB2-0.5 (Soil)	50.20	66.10	51.51
Average	**63.98**	**73.29**	**51.74**

2.4.1 Nonradiological Chemicals of Potential Concern

Nonradiological chemicals of potential concern included metals detected in samples collected from the diversion canal construction corridor that met the data evaluation criteria. Such metals as sodium, potassium, magnesium, calcium, zinc, and iron were excluded because they are considered essential nutrients and are only toxic at high concentrations. Also, the analytical data for cadmium and the triazine pesticides atrazine and simazine were reported as being analyzed for but not detected. Therefore, these were excluded as chemicals of potential concern. Chromium was detected in one soil boring composite sample at 114 mg/kg, slightly above the maximum concentration for the literature background range (100 mg/kg). However, this may be an outlier as the next highest chromium result for soil boring composite samples was 63.6 mg/kg. In addition, the maximum chromium results for shallow soil boring, surface soil composite, and sediment composite samples were 33.0 mg/kg, 21.0 mg/kg, and 10.8 mg/kg, respectively. Chromium was eliminated as a chemical of concern because the maximum detected result appeared to be an outlier, and the mean values for composite soil borings, shallow soil borings and composite surface soil samples does not exceed the mean literature background valve. The nonradiological chemicals of potential concern that were carried through the quantitative risk assessment included manganese and nickel because sample means exceeded the literature background means for these constituents. Table 2-7 lists these constituents with their corresponding minimum, maximum, mean, and 95 percent upper confidence limit (UCL) concentrations, and literature reference background concentrations.

2.4.2 Radiological Contaminants of Concern

Because the SLDP site is located east of RFP in an area potentially affected by past releases, evaluation of site-specific background radionuclide concentrations in soil is not possible. For this reason, radionuclides sampled for (detected in any media) that could originate at the RFP were retained as radionuclides of concern. Thus, the radionuclides

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Table 2-7
Summary of Nonradiological Contaminants of Concern
Standley Lake Diversion Project
Concentration (ppm)

Chemical	Shallow Soil Boring Samples (SB-0.5)				Soil Boring Composite Samples (SB-Comp)				Surface Soil Composite Samples (SL-Comp)				Sediment Composite Samples (SD)				Literature Reference Background Values[a]		
	Min.	Max.	Mean	95% UCL	Min.	Max.	Mean	95% UCL	Min.	Max.	Mean	95% UCL	Min.	Max.	Mean	95% UCL	Min.	Max.	Mean
Manganese	262.0	443.0	363.7	417.4	148.0	742.0	330.5	509.5	311.0	384.0	346.5	367.4	102.0	1400.0	531.3	969.8	30.0	5000.0	480.0
Nickel	13.2	30.4	18.5	23.7	11.0	30.0	16.4	19.5	8.6	16.9	13.6	16.5	8.6	13.7	9.9	12.0	ND	50.0	15.0

[a]Values from North American Soils by James Dragun and Andrew Chiasson, 1991, Hazardous Materials Control Resource Institute, Greenbelt, Maryland.

Note:

ND = Not Detected.

of concern for this assessment are Pu-239/240, Am-241, U-234, U-235, and U-238. A comparison of uranium concentrations detected in soil and sediment samples with reference background concentrations from the literature was made. Uranium concentrations detected are within the ranges expected for uranium in soils and sediments in the Rocky Mountain Area. However, because site-specific background values are not available for uranium, and the RFP is a potential source for this radionuclide, uranium isotopes (U-234, U-235, and U-238) were considered contaminants of concern for this assessment. The short-lived decay products of U-235 and U-238 are also considered to be present in equilibrium (equal activity) with these "parent" radionuclides. A summary of the minimum, maximum, average, 95 percent UCL, and literature reference background concentrations for each radionuclide of concern in each media is shown in Table 2-8.

Table 2-8
Summary of Radiological Contamination of Potential Concern
Standley Lake Diversion Project

Parameter	Shallow Soil Boring Samples (SB-0.5)				Soil Boring Composite Samples (SB-COMP)				Surface Soil Composite Samples (SL-COMP)				Sediment Composite Samples (SD)				Literature Reference Background Values[b]		
	Min. Detect (pCi/g)	Max. Detect (pCi/g)	Mean[a] (pCi/g)	95%[a] UCL	Min. Detect (pCi/g)	Max. Detect (pCi/g)	Mean[a] (pCi/g)	95%[a] UCL	Min. Detect (pCi/g)	Max. Detect (pCi/g)	Mean[a] (pCi/g)	95%[a] UCL	Min. Detect (pCi/g)	Max. Detect (pCi/g)	Mean[a] (pCi/g)	95%[a] UCL	Min. Detect (pCi/g)	Max. Detect (pCi/g)	Mean[a] (pCi/g)
Gross Alpha	16.3	23 [29.3]	21.3	23.78	10.2	21.8	15.7	19.37	24.1	124	44.7	76.84	9.93	21.8	15.42	18.67	17.0	48.0	30.7
Gross Beta	24.1	30.4 [33]	26.7	28.69	13.2	21.3	17.7	20.32	26.0	31.8 [33.3]	28.6	30.26	16.2	21.3 [25.0]	18.88	20.59	18.0	34.0	26.3
Am-241	0.009	0.133	0.0344	0.076	0.0079	0.0318	0.0138	0.0219	0.0357	2.08	0.434	1.099	0.0232	0.966	0.282	0.620	NA	NA	NA
Pu-239/240	0.009	0.253 [0.65]	0.0639	0.141	0.0047	0.0408	0.0099	0.0226	0.0553	0.453 [0.718]	0.173	0.292	0.0054	0.127 [0.206]	0.0758	0.123	-0.01	0.02	0.005
U-233/234	0.948	1.19	1.048	1.118	0.624	1.57	1.045	1.342	0.743	1.51	1.092	1.339	1.03	1.49	1.25	1.414	0.4	2.6	0.89
U-235/236	0.0419	0.0809	0.0644	0.079	0.0617	0.127	0.053	0.086	0.0671	0.192	0.062	0.121	0.0536	0.10	0.0623	0.0672	0	0.3	0.04
U-238	0.896	1.12 [1.25]	0.9947	1.061	0.519	1.39	0.978	1.246	0.683	1.31	1.062	1.242	0.761	1.49	0.979	1.206	0.4	2.3	0.96

[a]Mean and 95 percent UCL values were determined using calculated sample results as reported by the laboratory, including sample results less than the MDA.
[b]Reference background values taken from DOE 1990, Table 5-73 statistics for total radiochemical concentrations in background colluvial, weathered claystone, and weathered sandstone borehole samples.

Notes:

[ ] indicates a duplicate sample result that exceeded the original sample result. Maximum sample results (including duplicates) were used in the screening risk calculations for maximum ingestion and external exposure scenarios.
NA = Not Applicable.

Section 3
Toxicity Assessment

3.1 Introduction

The toxicity assessment is intended to relate information concerning potential adverse effects in humans as a result of exposures to chemicals and radionuclides of concern. The primary routes of exposure relevant to the planned construction of the diversion project include incidental ingestion of contaminated soils, inhalation of contaminated particulates, and direct exposure to external gamma radiation during construction activities.

3.2 Nonradiological Hazards

3.2.1 Background

Constituents detected in soils within the construction corridor consist of naturally occurring metals. The evidence used to derive toxicity information for nonradiological constituents is primarily from two sources: (1) experimental animal research and (2) limited human epidemiological or clinical studies. The first source considers that many of the effects seen in animals as a result of controlled exposures to chemicals are also assumed to occur in humans under similar exposure conditions. While these studies typically employ inordinately high doses administered to a variety of experimental animals and within a relatively short life span of the animal, they are used to extrapolate appropriate human concentrations (toxicity values). These toxicity values take into account various uncertainty factors and modifying factors that are used to describe the uncertainties in the values. These toxicity values that describe long-term or chronic exposures are used in assessing chronic human exposures.

The second source of toxicity information is from human studies in which occupational or accidental exposures have occurred. Detailed and sometimes elaborate statistical analyses are employed to assess cause and effect relationships. Again, uncertainty factors are generally used when extrapolating toxicity values based on these types of studies.

Two types of adverse health effects are described by the toxicity information, carcinogenic effects and noncarcinogenic (or systemic) effects.

3.2.1.1 Carcinogenic Effects

The carcinogenicity of a chemical relates to its ability to interact with an organism's genetic material (namely, deoxyribonucleic acid or DNA) in a variety of tissues and organs and produce abnormal cellular proliferation commonly called cancer (Klaassen, et al., Eds., 1986). Cancer induction is considered by EPA to be a non-threshold effect. That is, the risk of developing cancer increases linearly with each increment of exposure, without regard to a minimum or "threshold" level below which risk is zero. In addition, the onset of cancer is believed to be a delayed response in many cases in that symptoms generally do not occur immediately after exposure but rather several months or even years later.

The chemicals of concern within the construction corridor described in Section 2 that are known or suspected human carcinogens are presented in Table 3-1. Cancer slope factors (SFs), quantitative relationships between a dose of a chemical, and predicted upper bound incidence within the exposed population are presented along with EPA's weight-of-evidence classifications and the affected organs or tissues for each chemical of concern.

The SF is a plausible upper-bound of the probability of an effect (cancer) per unit of chemical over a 70-year lifetime (EPA, 1989a). The oral SF is used in estimating the probability of an individual developing cancer resulting from chronic ingestion of a carcinogenic chemical.

Table 3-1
Toxicity Values for Carcinogenic Chemicals of Potential Concern
Standley Lake Diversion Project

Chemical	Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	Route of Exposure
Nickel (Dust)	0.84	A	Lung/Nasal	Inhalation

[a]Integrated Risk Information System (IRIS) (EPA, 1992).

The weight-of-evidence classification is a system developed by EPA to support the evidence that a chemical causes cancer in humans. The system is organized around the quality and quantity of evidence supporting a chemical's carcinogenicity. The classes of carcinogenic compounds are as follows:

- <u>Class A: Human Carcinogen</u>. Sufficient evidence exists to support a cause and effect relationship of cancer in humans.

- <u>Class B: Probable Human Carcinogen</u>. Limited evidence exists to support cancerous effects in humans (Class B1) or sufficient evidence exists to support cancerous effects in various animal species (Class B2).

- <u>Class C: Possible Human Carcinogen</u>. No evidence exists to support cancerous effects in humans; however, limited evidence exists to support such effects in animals.

- <u>Class D: Not Classified</u>. Data to support cancerous effects in humans or animals does not exist or is of insufficient quality to render a judgment.

- <u>Class E: No Evidence of Carcinogenicity in Humans</u>. Both human and animal data are negative in terms of carcinogenic effects.

3.2.1.2 Noncarcinogenic Effects

Adverse toxic effects other than cancer may occur as a result of excessive exposure to certain chemicals. Such effects, also called systemic effects, may include injury or damage to tissues and organs as a result of inhibition or disruption of certain physiological or biochemical functions. Systemic toxicity may be classified as acute or chronic.

Acute toxicity refers to the rapid onset of symptoms after short exposure duration (usually less than 24 hr) to relatively high chemical concentrations. This effect is most typical of inhalation exposure to high concentrations of chemicals in air; however, exposure by ingestion to certain chemicals may also result in acute toxicity.

Chronic toxicity generally refers to a slower onset of symptoms as a result of continued exposure (from days to years) to low chemical concentrations. Such concentrations are termed sublethal because they are low enough not to cause immediate death. Chronic toxicity may be typical of both ingestion and inhalation exposure to very low concentrations of chemicals over long periods of time.

An assumption common to both acute and chronic types of systemic effects is the concept of threshold, which is a level of exposure above which toxic effects would be expected to occur. This concept is used to develop a reference dose (RfD) for human exposure. An oral RfD is an estimate of a daily human ingestion of a chemical that is likely to be without an appreciable risk of adverse health effect (EPA, 1991). This value is derived from animal dose-response experiments that identify the lowest chemical concentration that produces a measurable effect—the lowest observed adverse effect level (LOAEL) or the lowest concentration at which no effect is measurable, and the no observed adverse effect level (NOAEL). Uncertainty factors and modifying factors are applied when adjusting these values appropriately for human exposures. Such adjustments include extrapolating experimentally derived values between different animal species or between animals and humans and incorporating factors for the most sensitive human individuals. This adds a certain degree of conservatism in the derivation of RfDs. Generally, if an exposure to a chemical exceeds a chronic RfD, adverse toxic effects are likely to occur (EPA, 1989). Table 3-2 summarizes the RfD values for systemic chemicals of potential concern with associated confidence levels, critical effects, and uncertainty factors applied. Subchronic RfDs have been derived for certain chemicals. However, such values are currently not available for manganese or nickel; therefore, chronic RfDs are used in this assessment. Uncertainties in using these values rather than subchronic RfDs are discussed in Section 6.

Table 3-2
Toxicity Values for Noncarcinogenic Chemicals of Potential Concern
Standley Lake Diversion Project

Chemical	Chronic RfD (mg/kg-day)	Confidence Level[a]	Critical Effect	Uncertainty and Modifying Factors[b]
Manganese	0.1[c] (ing) 0.000116[c] (inh)	Medium Medium	CNS toxicity Adverse respiratory effects and psychomotor disturbances	UF = 300 (ing and inh) MF = 3 (ing and inh)
Nickel (Salts)	0.02[c] (ing)	Medium	Decreased body and organ weights	UF = 300 (ing) MF = 1 (ing)

[a]Relative confidence level for RfD based on animal studies (EPA, 1992).
[b]Uncertainty and modifying factors applied to account for extrapolations of animal data (EPA, 1992).
[c]IRIS (EPA, 1992).

3.2.2 Toxicity Profiles

Below are toxicity profiles for the nonradiological chemicals of potential concern that are considered in this human health risk assessment. A brief description of the toxic effects, including acute and chronic and cancer potential, is provided. It is not implied that the effects described will always occur in humans; such effects are dependent on, but not limited to, the chemical concentration in a particular medium, exposure characteristics such as route and duration of exposure, and absorbed dose. Toxicity profiles are not intended to be a comprehensive review of environmental transport or an extensive discussion of the data collected on adverse health effects. They are intended to provide a non-technical summary of the potential toxic effects associated with exposure to a chemical.

3.2.2.1 Manganese

Manganese is used in steel alloys and in the manufacture of dry-cell batteries, electrical coils, ceramics, glass, dyes, fertilizers, and welding rods. Manganese is present in biological material and is considered an essential element in trace quantities. Human intake of manganese is primarily through foods such as vegetables and nuts. Manganese is also present in geologic material in varying quantities. Soils in western states contain manganese in concentrations ranging from 30 to 5,000 parts per million (ppm), with a mean of 480 ppm (Dragun, 1991).

Toxicity to manganese generally occurs as a result of industrial and manufacturing exposures. Inhalation of high concentrations of manganese dust can cause manganese pneumonitis, a persistent pneumonia-like disease leading to epithelial necrosis and white blood cell proliferation.

Chronic inhalation exposures to manganese dust can cause more serious neurological conditions characterized by psychiatric symptoms such as irritability, motor skill

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disturbances, and compulsive behavior. Continued exposure can lead to encephalopathy and progressive deterioration of the central nervous system (CNS). Liver damage has also been described.

Manganese accumulates in the pancreas, liver, kidney, and intestines when exposed to low concentrations via ingestion. Clearance from the body occurs within 37 days.

3.2.2.2 Nickel

Nickel is used primarily in electroplating and in the manufacturing of metal alloys. Most exposures to nickel compounds is in industrial settings such as in the nickel-refining industry. Such exposures are generally to compounds of nickel such as nickel subsulfide, nickel oxides, nickel carbonyl, and nickel sulfate. As previously discussed, nickel in soils generally occurs as soluble nickel salts. Natural soils in Colorado may contain nickel ranging from nondetect to 50 ppm, with a mean of 15 ppm (Dragun, 1991).

While nickel may be an essential trace metal, exposure to high concentrations via inhalation may be fatal. Initial signs of exposure to nickel carbonyl may include headache, nausea, vomiting, and chest pain followed by severe cough, hyperpnea, cyanosis, gastrointestinal symptoms, and muscle weakness. Continued exposure may lead to pneumonia-like symptoms (chemical pneumonitis), cerebral edema, and death by respiratory failure. The RfD for nickel salts is based on abnormal body and organ weights (in rats) that resulted from oral exposure.

Chronic industrial exposures to nickel compounds via inhalation have been reported to cause rhinitis, nasal sinusitis, and nasal mucosal injury. Allergic contact dermatitis and other dermatological effects are the most frequent effects of dermal exposure to nickel compounds.

There is extensive epidemiological evidence suggesting excess cancer of the lung and nasal cavity for workers exposed to certain nickel compounds such as insoluble dusts of nickel subsulfide, vapor of nickel carbonyl, and nickel retinary dust. EPA classifies nickel subsulfide and nickel retinary dust as Group A carcinogens and nickel carbonyl as a Group B2 carcinogen. Carcinogenic risks from inhalation of nickel compounds are based on exposure to nickel dust.

3.3 Radiological Hazards

3.3.1 Background

This section, like the preceding section on chemical hazards, discusses the dose-response relationships and hazard identification associated with radiological contaminants identified at the SLDP site.

The assessment of risks associated with exposure to ionizing radiation is similar in some ways to the assessment of risks associated with chemical carcinogens. Like carcinogenic chemical risks, radiological risks are usually expressed as an increased probability of cancer. However, radiological risks have historically been expressed as the increased probability of induction of a fatal cancer, while chemical risks are usually expressed as the increased probability of cancer incidence. This assessment expresses radiological risks as increased risk of total cancer incidence, in accordance with EPA methods outlined in RAGS.

Another difference between chemical and radiological risk assessment methods lies in the use of radiation dose equivalent as the primary expression of harm from exposure to radiation. Radiation risks are often calculated by first determining the dose equivalent received (in rems) and then applying a factor that converts dose equivalent to risk. In chemical risk assessments, intake of chemicals (usually expressed in mg/kg-day) is converted to risk, using an intake to risk conversion factor (SF). This assessment uses the intake to risk approach to determine radiological risks. However, effective dose equivalent values are also calculated for use in comparison to standards.

To assist in understanding the following discussions, several common radiological terms need explanation. The degree of damage from radiation in biological systems varies in proportion to how much energy is transferred to the tissue over a linear track length by the radiation. This concept is referred to as linear energy transfer (LET). High-LET radiation causes a high degree of ionization by depositing a large amount of energy over a very short distance. Alpha particles are the most common example of high-LET radiation. Low-LET radiation deposits energy over a much longer range and creates less densely ionized regions. Beta particles, gamma rays, and X rays are examples of low-LET radiation. For a given amount of deposited total energy (dose), high-LET radiation will deposit energy over a shorter distance and, thus, will produce significantly greater biological damage than low-LET radiation.

A rad is defined by the International Commission on Radiation Units and Measurements (ICRU) as the amount, or dose, of ionizing radiation absorbed by any material, such as human tissue. Radiation absorbed dose is expressed as energy per unit mass. One rad is equivalent to 100 ergs of energy absorbed by one gram of absorbing material. A rem (which stands for *roentgen equivalent man*) is a unit of dose equivalent used in radiation protection to measure the amount of damage to human tissue from a dose of ionizing radiation. Dose equivalent is the product of absorbed dose and a quality factor. A millirem, or mrem, is 1/1,000th of a rem. A typical X ray yields a dose of approximately 30 mrem. For low-LET radiation, one rad is equal to one rem. For high-LET radiation (alpha radiation), one rad is equal to 20 rem.

3.3.2 Radiological Hazard Identification

Radiation produces damage in biological systems through ionization of molecules. Damage may occur directly, as when a chromosome breaks into smaller pieces after

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absorption of energy from radiation. Damage may also occur indirectly through ionization of water molecules to produce highly reactive free radicals. The free radicals may react with other cellular compounds and cause damage through oxidation reactions.

The biological effects of radiation are classified as either nonstochastic or stochastic effects. Nonstochastic effects are those for which severity is related to dose, and for which an effective threshold exists below which clinically observable effects do not occur. Examples of nonstochastic effects include reddening of the skin (erythema) and cataracts. Nonstochastic effects are principally associated with high levels of radiation exposure (>10 rem). It is highly unlikely that individuals working on the SLDP could ever receive radiation doses that would cause nonstochastic effects, since radionuclide soil concentrations are relatively low. Stochastic effects are those for which the probability of occurrence increases with the cumulative dose. The stochastic effects associated with low levels of radiation exposure include cancer, genetic effects, and damage to a developing fetus. Only the stochastic effects of radiation exposure are considered in this assessment. The following sections provide a summary of the major stochastic effects of radiation exposure.

3.3.2.1 Carcinogenic Effects

Ionizing radiation is a demonstrated human carcinogen. Data exist that correlate high exposures of radiation to cancer induction in humans. In general, scientists agree that the probability of cancer increases with dose, but scientists continue to debate which dose-response model most accurately predicts the effects of low-level radiation exposure. Current radiation protection standards are based on the assumption that each increment of radiation exposure causes a linear increase in the risk of cancer (the linear nonthreshold hypothesis).

The U.S. National Academy of Sciences, National Research Council, Committee on the Biological Effects of Ionizing Radiation (BEIR, 1990) recently completed a study entitled

Health Effects of Exposure to Low Levels of Ionizing Radiation (known as BEIR V). The study included information from the continuing epidemiological studies of the Japanese survivors of the atomic bomb. The BEIR V Committee concluded that the linear nonthreshold dose-response model most accurately predicts the increased risk of most forms of cancer from exposure to low doses of radiation. The BEIR V Committee also increased the cancer risk estimates for radiation exposure from the 1980 BEIR III Report by a factor of 3 to 4, based primarily on results of studies that reevaluated the actual radiation doses received by the Japanese survivors of the atomic bomb.

EPA also recently finished evaluating the cancer risk from radiation exposure as part of the safety analysis for radionuclide standards for atmospheric releases (known as NESHAPS). Although EPA's methodology differs slightly from that of the BEIR V Committee, the results of both studies are similar. Table 3-3 includes a summary of the current factors for estimating risk used by EPA for cancer induction and cancer mortality from radiation exposure. These factors for estimating risks are in terms of the excess cancer induction and excess cancer deaths expected in a population of 1 million people, each person exposed to a radiation dose of 1 rad (risk/10^6 rad).

3.3.2.2 Genetic Effects

Radiation can cause damage to cells by changing the number, structure, or genetic content of the genes and chromosomes in the cell nucleus. These heritable radiation effects are classified as either gene mutations or chromosome aberrations. Gene mutations and chromosome aberrations may occur in either somatic (body) or germ (reproductive) cells. When the mutation or aberration occurs in a somatic cell, the damage is expressed in the exposed individual. For somatic-cell mutations, the worst consequence of the damage is cancer induction. When the mutation or aberration occurs in a germ cell, the resulting damage may be expressed in the descendants of the exposed individual.

Table 3-3
Summary of Current EPA-Recommended Radiation Risk Factors[a]
Standley Lake Diversion Project

Risk	Significant Exposure Period	Risk Factor Effect/10^6 Rad	
		Nominal	Range
Low-LET			
Carcinogenic Effects			
Fatal Cancers	Lifetime	390	120-1,200
All Cancers	Lifetime	620	190-1,900
Genetic Effects			
Severe hereditary defects, all generations	30-year reproductive generation	260	60-1,100
Teratogenic Effects[b]			
Severe mental retardation	Weeks 8 to 15 of gestation	4,000	2,500-5,500
Malformation	Weeks 2 to 8 of gestation	5,000	---
Preimplantation loss	Weeks 0 to 2 of gestation	10,000	---
High-LET			
Carcinogenic Effects			
Fatal Cancers	Lifetime	3,100	960-9,600
All Cancers	Lifetime	5,000	1,500-15,000
Genetic Effects			
Severe hereditary defects, all generations	30-year reproductive generation	690	160-2,900

[a]Taken from Table 6-27 in EPA/520/1-89-005 (EPA, 1989b).
[b]The range assumes a linear, nonthreshold dose response. However, it is plausible that a threshold may exist for this effect.

Genetic effects have not been observed in follow-up epidemiological studies of human populations exposed to low doses of radiation. There is general scientific agreement, however, that these effects may be occurring in numbers so low that they are not detectable in the study populations. Because of the lack of conclusive human data, animal studies are used to determine risk factors for heritable effects in humans.

The results of animal studies have shown that radiation increases the spontaneous, or natural, mutation rate. No new types of mutations have been attributed to radiation exposure. Estimates based on extrapolation from these animal studies are that at least 100 rad of low-dose rate, low-LET radiation are needed to double the spontaneous mutation rate in man. Current human dose response models, however, assume that the probability of genetic damage increases linearly with radiation dose, and there is no evidence of a "threshold" dose for initiating heritable damage to germ cells.

Table 3-3 includes a summary of the current information on the risks of genetic effects from radiation exposure. The risk factors are stated in terms of serious hereditary effects per million live-born babies for an average population exposure of 1 rad of low-LET radiation in a 30-year generation. In estimating risks of genetic effects, EPA uses the values of 20 serious heritable effects per generation and 260 serious heritable effects for all generations (1,000 years) in a birth cohort (people of the same age) that are due to exposure of the parents to 1 rad per generation.

3.3.2.3 Teratogenic Effects

Relatively high doses of radiation exposure have been shown to produce abnormalities in animals and humans exposed in utero. The effects of radiation exposure to the fetus vary with the stage of gestation. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has developed quantitative risk estimates for effects of prenatal irradiation (primarily mental retardation) over the different stages of pregnancy. Possible risks of fetal radiation exposure include mental retardation, development of fatal cancer after birth, malformation, and preimplantation loss (spontaneous abortion). Table 3-3 includes a summary of the current EPA risk factors for radiation exposure to the fetus.

3.3.2.4 Summary

Cancer induction through exposure to low levels of radiation constitutes the most significant potential consequence of exposure. The risks of heritable effects from radiation exposure are much lower than cancer induction for the first few generations. Carcinogenic effects can be induced at any point during a lifetime. However, exposures must occur during a specific period during gestation for the risks of effects on the developing fetus to be significant. In most cases, the cumulative risk of cancer is much higher than the risk of fetal effects or genetic effects. For these reasons, cancer induction is used as the basis for assessing the radiation risks to offsite receptors around the SLDP. Table 3-4 provides a summary of the radionuclide-specific dose conversion factors and cancer incidence risk factors used for this risk assessment.

3.3.3 Exposure to Natural Background Radiation

The health effects of radiation exposure are difficult to evaluate at low doses, partly because radiation is present naturally in the environment. The National Council on Radiation Protection and Measurements (NCRP) estimates that, on average, the background radiation dose to each individual is approximately 360 mrem/year (NCRP, 1987a). Most of this dose is attributed to radon-222 and its short-lived decay products. Table 3-5 summarizes the average annual doses from each source contributing to background radiation exposure.

Unlike many risks, the risks from exposure to naturally occurring background radiation are largely unavoidable. An evaluation of the risk from exposure to average levels of background radiation establishes a benchmark for judging the additional risk from

Table 3-4
Dose Conversion Factors and Risk Factors for the Standley Lake Diversion Project Radiological Risk Assessment

	Dose Conversion Factors			Risk Factors		
				Cancer Incidence		
Nuclide	Ingestion (mrem/pCi)	Inhalation (mrem/pCi)	External Exposure (mrem-g/pCi-hr)	Ingestion $(pCi)^{-1}$	Inhalation $(pCi)^{-1}$	External Exposure (risk-g/pCi-yr)
U-238 + D	2.55×10^{-4}	1.18×10^{-1}	7.5×10^{-6}	2.8×10^{-11}	5.2×10^{-8}	3.6×10^{-8}
U-235 + D	2.66×10^{-4}	1.23×10^{-1}	3.8×10^{-5}	1.6×10^{-11}	2.5×10^{-8}	2.4×10^{-7}
U-234	2.83×10^{-4}	1.33×10^{-1}	5.7×10^{-8}	1.6×10^{-11}	2.6×10^{-8}	3.0×10^{-11}
Am-241	3.64×10^{-3}	4.43×10^{-1}	4.3×10^{-6}	2.4×10^{-10}	3.2×10^{-8}	4.9×10^{-9}
Pu-239	3.69×10^{-4}	3.08×10^{-1}	4.2×10^{-8}	2.3×10^{-10}	3.8×10^{-8}	1.7×10^{-11}

Notes:

+ D indicates that daughter radionuclides are included in the risk and external dose calculations. Internal dose factors account for buildup of daughters, assuming intake of pure parent radionuclide.

Sources:

Internal dose factors were taken from EPA (1988a) and the DFINT program developed by K. F. Eckerman at the Oak Ridge National Laboratory (ORNL). Cancer incidence factors were taken from the Health Effects Assessment Summary Tables (HEAST) (EPA, 1992). Dose factors for external radiation exposure were taken from NUREG/CR-5512 (NRC, 1990).

Table 3-5
Average Annual Effective Dose Equivalents from Ionizing Radiation for a Member of the U.S. Population
Standley Lake Diversion Project

Source	Effective Dose Equivalent (mrem)	Effective Dose Equivalent (Percent)
NATURAL		
Radon	200	55
Cosmic	27	8
Terrestrial	28	8
Internal	39	11
Total Natural	294	82
ARTIFICIALLY INDUCED		
Medical		
X-Ray Diagnosis	39	11
Nuclear Medicine	14	4
Consumer Products	10	3
Other		
Occupational	<1	<0.3
Nuclear Fuel Cycle	<1	<0.03
Fallout	<1	<0.03
Miscellaneous[a]		
Total Artificial	63	18
Total Natural and Artificially Induced	**357**	**100**

[a]DOE facilities, smelters, transportation, and other sources.

Source: National Research Council, 1990.

releases of radionuclides to the environment. The results of an evaluation of background radiation risk prepared by EPA (1989d) are summarized in this subsection.

The major components of exposure to background radiation and the associated annual average exposure are shown below. These values are taken from Report No. 93 of the NCRP (NCRP, 1987b). They represent annual average values for radiation exposure across the United States.

- Low-LET

Cosmic radiation	27 mrem
Terrestrial radiation	28 mrem
Internal radiation	39 mrem
Total	94 mrem/year

(1 mrad = 1 mrem for low-LET radiation, so 94 mrem/year = 94 mrad/year)

- High-LET

Radon	200 mrem/year

The risk of exposure to low-LET radiation is determined by multiplying the annual average exposure by the number of years of exposure (70.7 for lifetime) and multiplying this result by EPA's fatal cancer risk value of 3.9×10^{-7} per mrad. This results in lifetime fatal cancer risk of 2.6×10^{-3}, or about 0.26 percent of all deaths. Current U.S. vital statistics data show that the probability of dying of cancer is approximately 16 percent. Thus, low-LET background radiation exposure is responsible for approximately 0.0026/0.16, or 1.6 percent, of all cancer deaths in the United States.

The risk of exposure to radon is determined differently from the procedure for other types of radiation exposure. The unit of concentration for radon is the working level (WL). The WL is defined as the concentration of radon daughter products in 1 L of air that results in the emission of 1.3×10^5 million electron volt (MeV) of potential alpha energy. A working-level month (WLM) is defined as the exposure resulting from breathing air at 1 WL for 1 month (170 hr). The 200 mrem/year radon exposure discussed above equates to approximately 0.25 WLM/year.

The risk of radon exposure is determined by multiplying the annual average exposure by the number of years of exposure (70.7 for a lifetime) and multiplying this result by EPA's radon risk factor of 360 fatal lung cancers per million WLM. This results in a lifetime risk of fatal cancer of 6.4×10^{-3}, or about 0.64 percent of all deaths. In 1980, approximately 5 percent of all deaths were due to lung cancer. Thus, approximately 0.0064/0.05, or 13 percent, of lung cancer deaths could be attributed to background radon exposure.

Two other categories of natural radiation exposure are exposure of lungs and of bone surfaces to naturally occurring alpha emitters other than radon. Values for fatal cancer risk for these categories are not shown because they are a factor of 100 to 1,000 less than the risks shown for low-LET and radon exposures.

Some indication of the potential total risk from exposure to natural background radiation may be obtained by summing the risks from low-LET exposure and radon exposure. The result of summing these categories is risk of a fatal cancer of 8.8×10^{-3} (almost 1 in 100) over a lifetime of exposure. This value probably represents the upper boundary of risk because of the large uncertainties associated with each of the components. In particular, the risk value for radon exposure may be biased on the high end because it is based on the overall U.S. population: male, female, smokers, and nonsmokers.

Section 4

Exposure Assessment

The exposure assessment consists of three main elements: (1) characterization of the exposure setting; (2) identification of exposure pathways; and (3) quantification of exposure.

4.1 Characterization of the Exposure Setting

As previously discussed, the SLDP is designed to physically isolate Standley Lake from potentially contaminated runoff from the RFP (see Figure 1-1). This runoff currently flows via Woman Creek into Standley Lake. This surface water reservoir serves as a primary supply for drinking water and irrigation; it is also used for boating, sailboarding, and fishing. Land use around Standley Lake is predominantly residential, interspersed with linear parks and open space lands. Rangeland is located to the west and northwest, a small amount to the west is used for agricultural production of hay. Municipal and county parks to the north of Standley Lake are used for recreational activities such as camping, picnicking, and fishing. Future land uses will include additional parks and open space. Figures 4-1 and 4-2 show the existing and future land uses surrounding Standley Lake.

The SLDP includes construction of diversion ditches, canals, and retention basins. Woman Creek Reservoir (WCR) is designed to intercept and store Woman Creek flows up to the 100-year storm event. The diversion canal will route releases from WCR around the northern side of Standley Lake to Big Dry Creek below the Standley Lake Dam. Nearby residential areas are located primarily to the northeast and southeast of the east retention pond on Big Dry Creek—both north and south of and adjacent to the proposed canal route, and to the south of WCR. Currently, the closest resident to the

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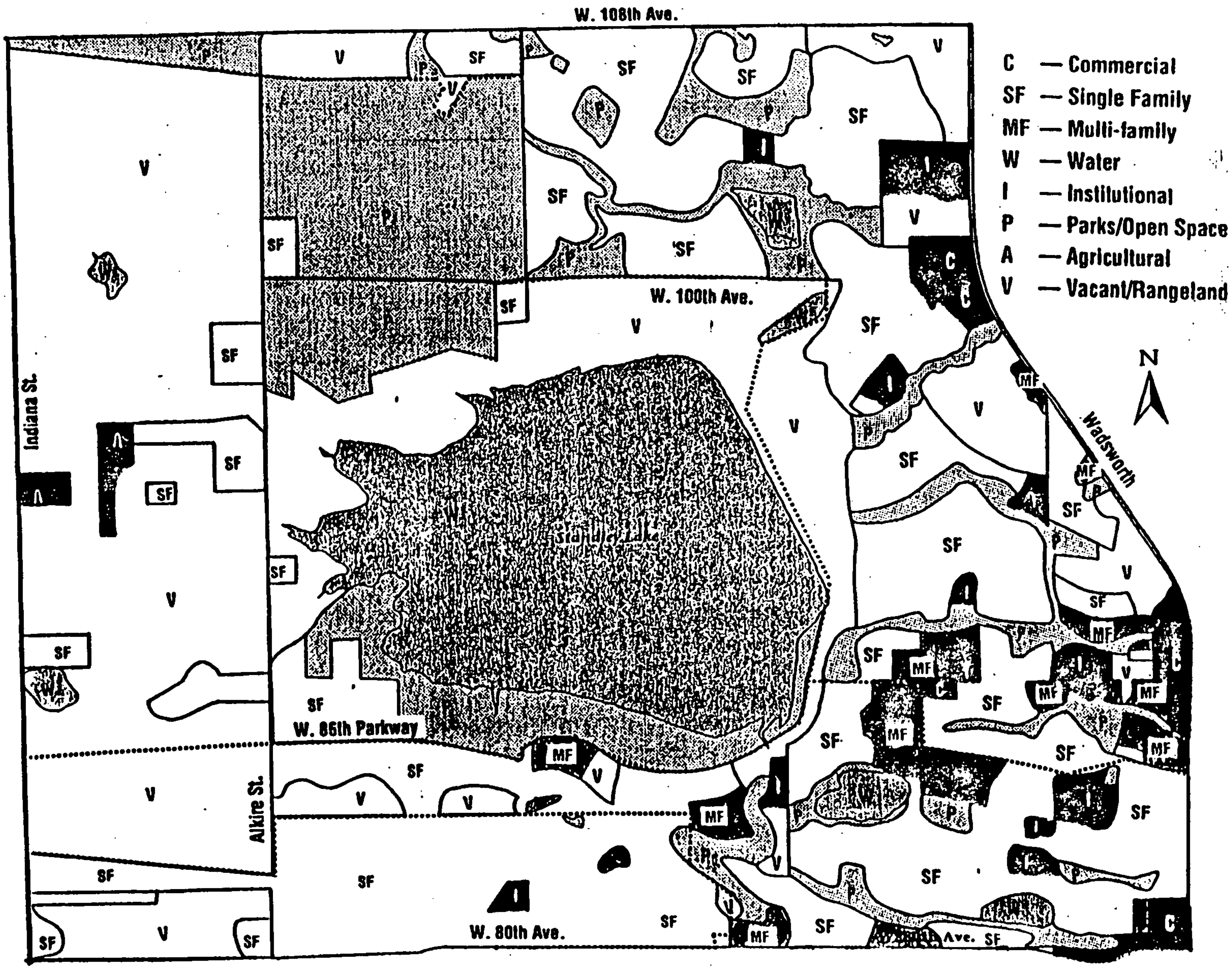

Figure 4-1
Standley Lake Study Area
Existing Land Use

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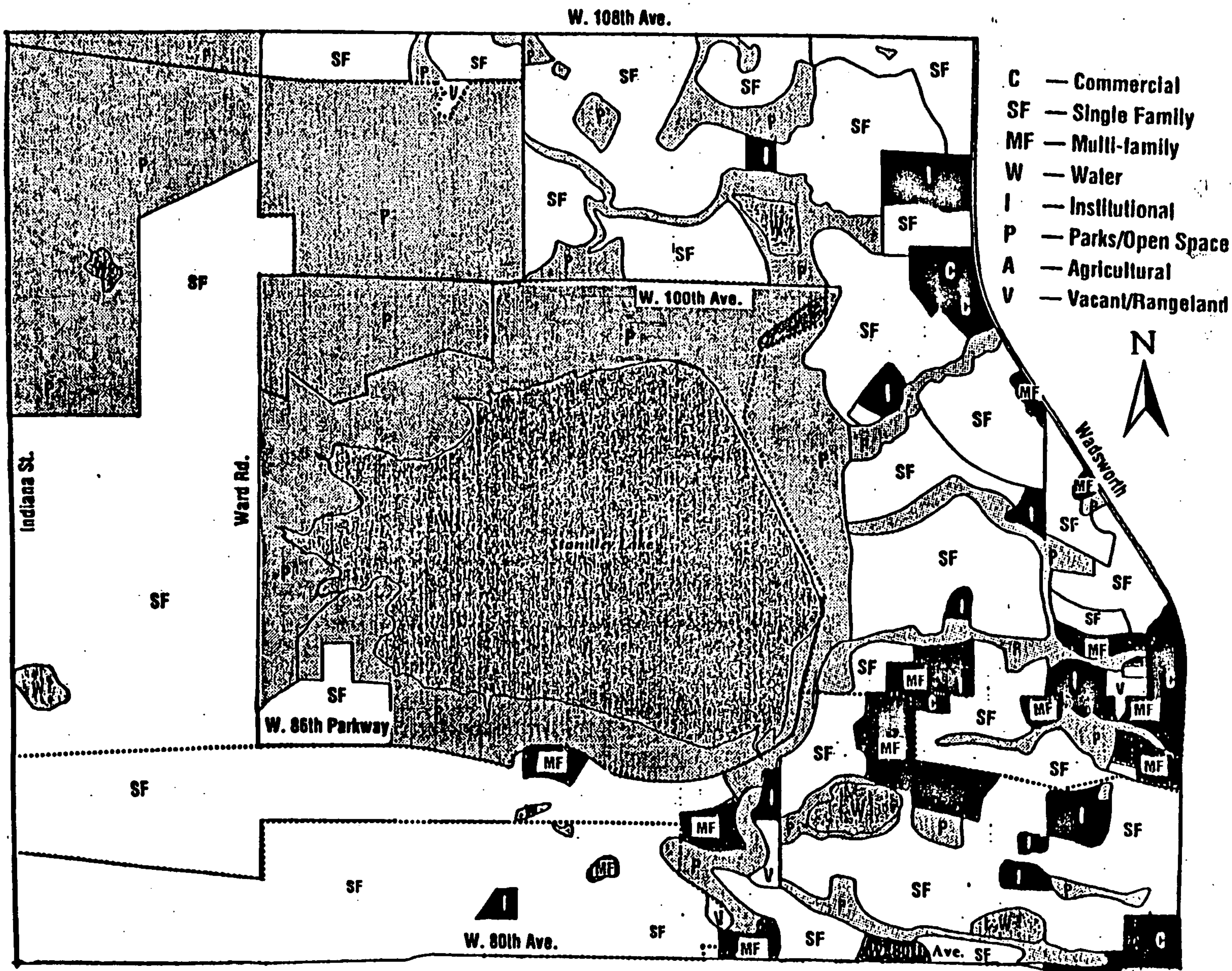

Figure 4-2
Standley Lake Study Area
Future Land Use

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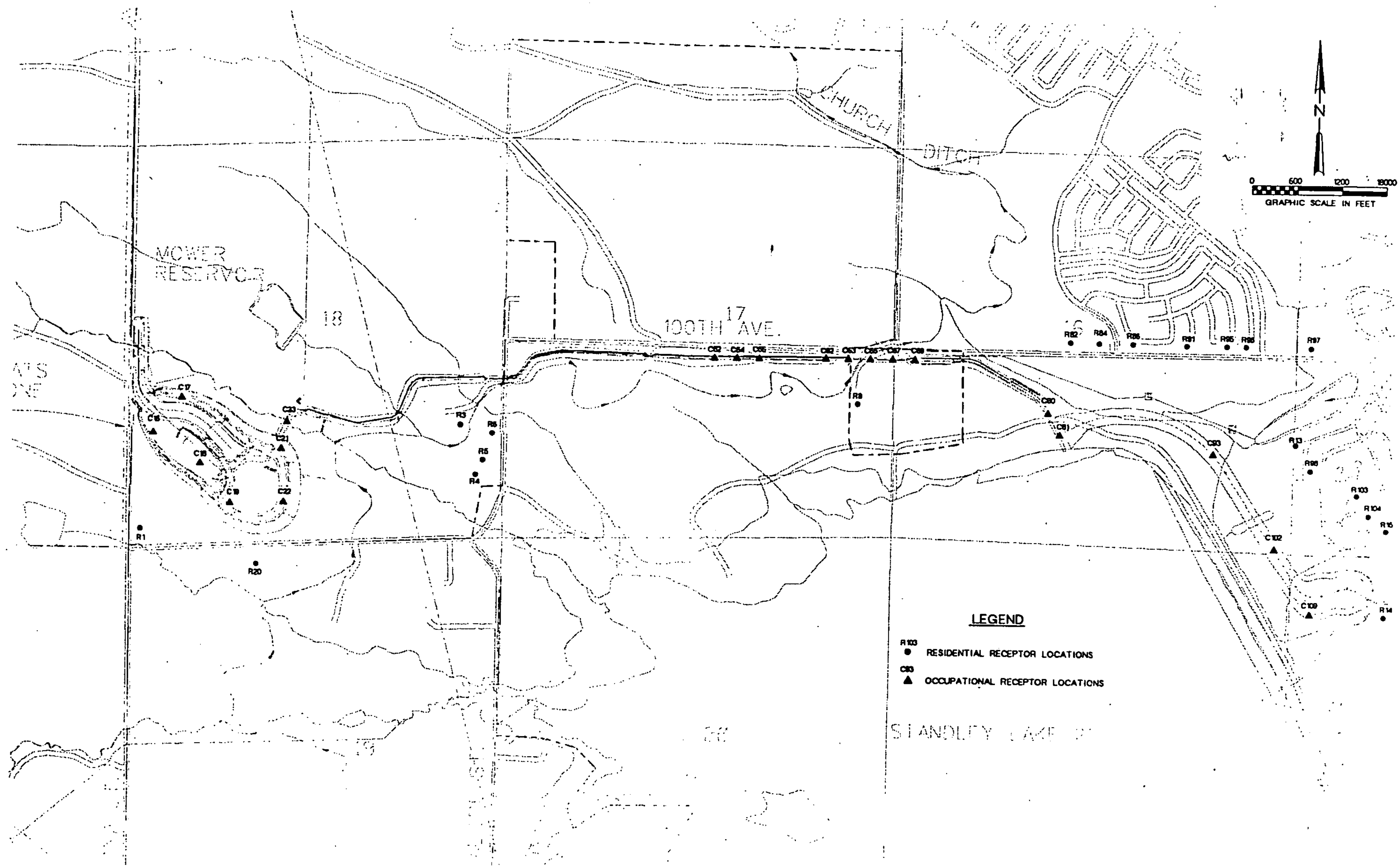

FIGURE 4-2
HIGHEST 20 OCCUPATIONAL
AND RESIDENTIAL RECEPTOR LOCATIONS

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proposed canal construction area is approximately 200 ft away. A more detailed description of the SLDP is provided in the *Draft Environmental Assessment, Standley Lake Diversion Project* (DOE, 1992).

Construction activities will involve scraping, grading, excavating, stockpiling, hauling, and backfilling with potentially contaminated soil. These activities will result in the generation of contaminated dust and subsequent migration by winds and resultant deposition. A potential for exposure to these contaminants exists because varying concentrations of heavy metals and radionuclides have been detected in the soil in the proposed construction area.

4.2 Identification of Exposure Pathways

An exposure pathway is the means by which a contaminant moves through the environment from a source and interfaces with a receptor. A complete exposure pathway consists of four elements: (1) a source of contamination and release mechanism, (2) a transport medium and mechanism of transfer from one medium to another, (3) a point of potential receptor contact, and (4) a route of exposure. These elements are included in the conceptual site model (CSM) for the SLDP (see Figure 4-3).

As shown in the CSM, the source of contamination is surface and subsurface soils in the proposed construction corridor. The contaminants of concern were previously shown in Tables 2-3 and 2-4. These contaminants associated with suspended particulates may be released into the air as a result of physical disruption of soil during construction. It is assumed that activities will generate dust throughout the construction duration of 1 year. Also, direct exposure to gamma radiation may be a possible exposure mechanism because much of the radionuclide contamination is considered to be within the surficial soil (i.e., top 6 in.).

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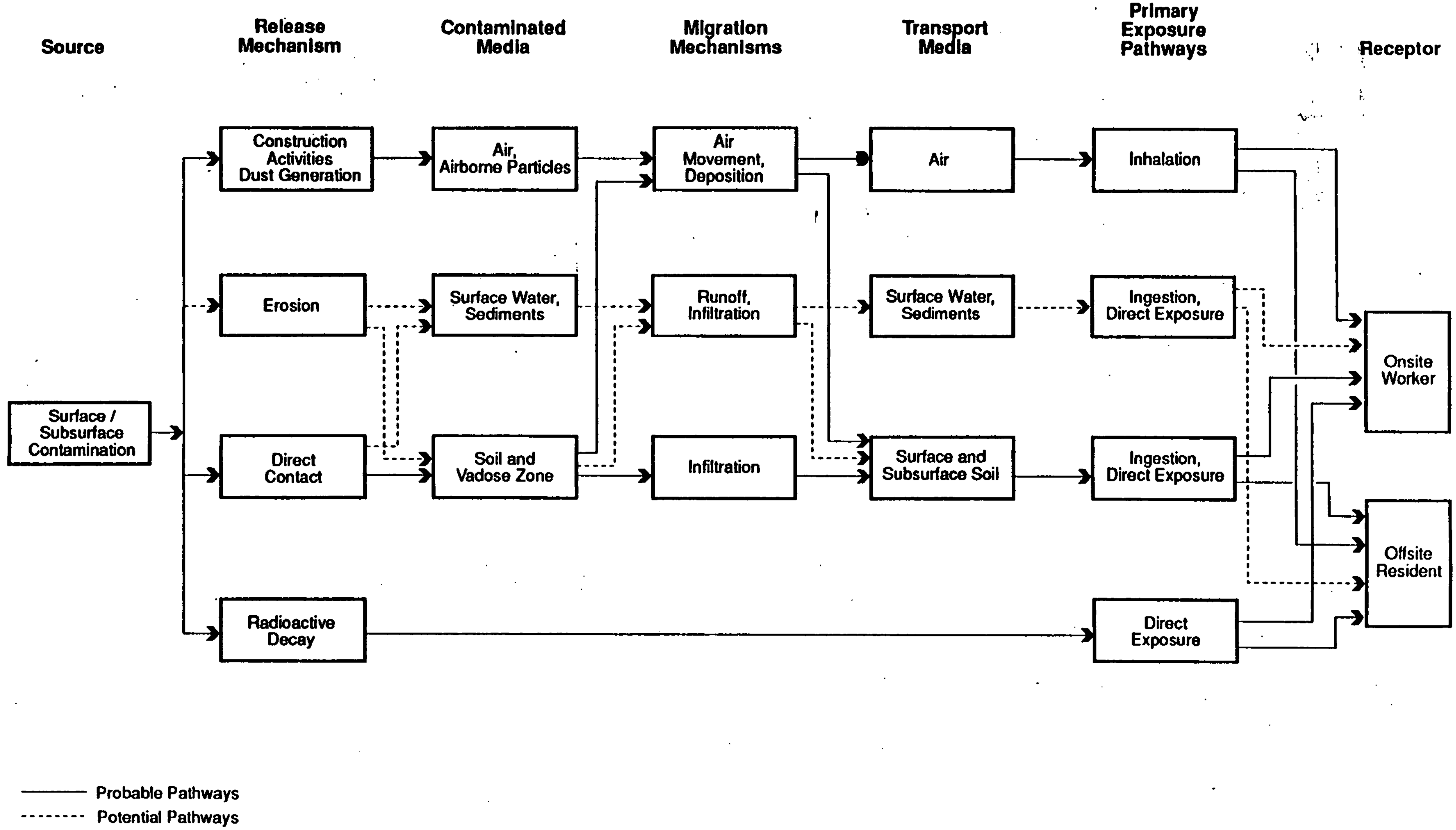

Figure 4-3
Conceptual Site Model
Standley Lake Diversion Project Risk Assessment

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Air movement and deposition are primary transfer mechanisms of contamination from the source to a potential receptor at the site.

The medium of concern, in terms of potential receptor contact, is suspended air, contaminated particulates, and surface soil. Exposure points for receptor contact include contact with surface soils and excavated subsurface soils within the construction corridor and suspended dust in the construction corridor and in nearby residential areas.

The receptor scenarios that are considered for this risk assessment associated with the construction of the SLDP include onsite construction workers and offsite residents. Because of concerns about exposures to discrete locations of elevated contamination, a short-term construction "hot spot" scenario is evaluated. Also, because much of the land adjacent to the diversion canal will be used for recreational facilities, a longer term recreational receptor exposure scenario (e.g., after construction of the SLDP) is included.

A route of exposure is the means by which a contaminant is internalized or gains entry into the body. The routes of exposure evaluated for the construction worker and residential receptor scenarios include the following:

- Incidental ingestion of contaminated soil
- Inhalation of contaminated particulates
- Direct gamma exposure

The routes of exposure for the future recreational receptor and construction "hot spot" scenario include the following:

- Incidental ingestion of contaminated soil
- Direct gamma exposure

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4.2.1 Incidental Soil Ingestion

Incidental soil ingestion can occur during outdoor activities. For example, soil ingestion by hand-to-mouth contact can occur through the consumption of food held in unwashed hands or through activities such as smoking. Actual amounts ingested vary on the basis of site conditions and age. This exposure route is considered for the construction worker and nearby resident during construction activities only. Post-construction land conditions are expected to consist of grass cover and landscaping that will serve to limit contact with soils. However, this exposure route is assessed for the future recreational receptor because of the potential for enhanced contact during outdoor activities in or around the former canal construction zone.

4.2.2 Inhalation of Contaminated Particulates

As previously discussed, construction activities will generate dust that may be contaminated with the constituents of concern. Normal breathing during outdoor activities in which construction activities are occurring may lead to inspiration of respirable particulates. However, general construction practices involve controls to mitigate dust dispersion. This evaluation assumes that controls will not be used in order to be conservative in estimating intake.

An inhalation route of exposure is not considered under the future recreational scenario because the ground within and surrounding the canal area is expected to be covered with concrete, grass, or other ground cover that will prevent wind erosion and significant dust generation.

Inhalation is not considered for the construction "hot spot" scenario because the discrete sources of contamination are considered too small to contribute significantly to airborne contaminant concentrations.

4.2.3 Direct Gamma Exposure

Because of the surficial soil contamination, exposure to gamma radiation is possible as a result of direct exposure to soils within the construction corridor. While construction workers are expected to be involved in direct contact with these soils, it is assumed that residents will also have access to these soils, although access will be somewhat limited.

Because potentially contaminated soils from the construction area will be used as backfill material, a longer term exposure to gamma radiation is assessed for a future recreational receptor. This exposure scenario is based on intermittent use of the proposed park facilities.

4.3 Quantification of Exposure

Quantification of exposure involves estimating the magnitude, frequency, and duration of exposure for each pathway being evaluated in the risk assessment. This is done by estimating exposure concentrations and calculating receptor intakes.

4.3.1 Exposure Concentrations

Data collected during the field sampling effort at locations within the construction corridor are used in assessing exposure concentrations. Specific sample type and location are described in the Field Sampling Plan (FSP), Analysis, and QAPP (CH2M HILL, 1992). These include six composite surface soil samples, six composite subsurface soil samples, six discrete boring samples covering the surface interval to 0.5 ft bls, and six composite sediment samples. Complete field sample results have previously been submitted in the January 18, 1993, technical memorandum (TM) (CH2M HILL, 1993). The data summarizing the minimum, maximum, mean, 95 percent UCL, and literature reference background concentration values of the contaminants of concern are shown in Tables 2-7 and 2-8.

The exposure assessment approach discussed in the risk assessment protocols memorandum (CH2M HILL, 1993) was modified to allow the use of a conservative "screening" risk evaluation to determine if there was a need to calculate location-specific risks (as described in the memorandum). As a "worst case" assumption, maximum concentrations for each contaminant of concern in a given composite sample type, regardless of sample location, were used as the exposure concentration to determine screening level risks. This approach was used to estimate the upper bound exposure that could possibly occur at the site under the assumed construction worker, construction "hot spot," residential, or recreational exposure scenarios. With this approach, upper bound screening level risks that are less than 1×10^{-6} indicate that it is not necessary to further evaluate average or location-specific risks, since the average and location-specific risks would be less than 1×10^{-6}. This approach is used for incidental soil ingestion and direct gamma exposure for each of the four exposure scenarios listed above.

The upper bound screening approach was not used for inhalation exposures because intake from inhalation is driven by average ambient dust concentrations calculated with average meteorological conditions, and inhalation is the primary pathway of exposure at this site. Further, it is not possible to determine exact sources of any given airborne contaminant concentration (e.g., contaminated dust at a particular receptor location may have originated several miles away). Therefore, the average and 95 percent UCL on the arithmetic mean contaminant concentrations from composited surface soil samples and composited soil boring samples are used as input concentrations to determine receptor airborne contaminant intakes. Below is a brief discussion of the protocols used for modeling dust concentrations, with a summary of the results from the modeling. A complete description of the results of the dust modeling may be found in the Nicholl Environmental Associates Report on Fugitive Dust Dispersion Modeling (Nicholl, 1993).

4.3.1.1 Ambient Dust Modeling Protocol

EPA's Fugitive Dust Model (FDM) was selected as the most appropriate dispersion model to apply to this analysis. To be as realistic (yet conservative) as possible, modeled dust concentrations were based on construction activities that generate dust from disturbances of topsoil or subsurface soil. Concentrations reported are total dust, which includes the respirable (PM_{10}) fraction. A 6-year record of meteorological data (1984 through 1989) from Stapleton Airport, located approximately 14 miles southeast of the project area, was processed into an annual Joint Frequency Distribution (Stability Array or STAR) for use in the FDM. Construction activity-specific parameters were used to model dust generation for input to the FDM. A total of 113 receptor locations within the construction zone and nearby residential areas were designated for calculation of dust concentrations.

Two dust concentration values each are calculated for the receptor locations, one for topsoil dust and one for subsurface dust. The dust concentrations are combined with the appropriate soil concentrations (from surface soil or subsurface soil samples) to estimate a total airborne contaminant concentration, as shown by the formula below:

$$\text{ACC (or AAC)} = (C_{top} \times DC_{top} \times CF) + (C_{sub} \times DC_{sub} \times CF)$$

where:

ACC =	airborne chemical contaminant concentration ($\mu g/m^3$)
AAC =	airborne radioactivity concentration (pCi/m^3)
C_{top} =	contaminant concentration in topsoil ($\mu g/g$ or pCi/g)
DC_{top} =	dust concentration from topsoil ($\mu g/m^3$)
CF =	conversion factor (10^{-6} $g/\mu g$)

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C_{sub} = contaminant concentration in subsurface soil ($\mu g/g$ or pCi/g)

DC_{sub} = dust concentration from subsurface soil ($\mu g/m^3$)

Average airborne contaminant concentrations are calculated by using average dust concentrations and average contaminant soil concentrations. Upper bound airborne contaminant concentrations are calculated using 95 percent UCL dust concentrations and 95 percent UCL soil concentrations. Upper 95 percent confidence limits on the arithmetic mean for sample concentrations and dust concentrations are based on the following formula:

$$95 \text{ percent UCL} = \text{Average} + t_{05} \times \text{STD}/(N)^{0.5}$$

where:

N = the number of samples

t_{05} = the t-test statistic for the 95 percent UCL

STD = the standard deviation of the sample set

Figure 4-4 shows the 20 construction and 20 residential receptor locations used in the model which showed the highest dust concentrations. A complete listing of construction and residential receptor point dust concentrations is shown in Appendix A. A summary listing the average and 95 percent UCL modeled dust concentrations for construction and residential receptors is presented in Table 4-1. A summary of the exposure point concentrations for ingestion, inhalation, and direct external gamma exposure is shown in Table 4-2 for each exposure scenario and pathway.

4.3.2 Intake Calculations

Quantification of exposure includes estimating the intake of contaminants of concern in various media via the exposure routes discussed above using appropriate exposure

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Table 4-1
Summary of Annual Average Receptor Dust Concentrations
Standley Lake Diversion Project Risk Assessment

Receptor Group	Annual Average Concentration			
	Topsoil Dust		Subsurface Dust	
	Receptor Average[a] ($\mu g/m^3$)	95% UCL[b] ($\mu g/m^3$)	Receptor Average[a] ($\mu g/m^3$)	95% UCL[b] ($\mu g/m^3$)
Construction	151.1	170.0	4117.7	4383.9
Residential	51.9	56.0	2051.9	2309.4

[a]Average is a spatial average across the receptors in a receptor group (construction or residential).
[b]95% UCL is the 95% UCL of the arithmetic mean of dust concentrations for receptors in a receptor group.

Table 4-2
Summary of Exposure Point Concentrations
Standley Lake Diversion Project Risk Assessment

Scenario/Pathway	Exposure Concentration Average	Exposure Concentration Upper Bound	Comments
Construction "Hot Spot"			
Ingestion of soil/sediment			
Direct external gamma exposure			
Manganese	NA	4,430 mg/kg	Maximum concentration from discrete shallow soil boring (upper interval) sample multiplied by 10.0.
Nickel	NA	304 mg/kg	
Am-241	NA	1.33 pCi/g	
Pu-239	NA	6.5 pCi/g	
U-234	NA	11.9 pCi/g	
U-235	NA	0.81 pCi/g	
U-238	NA	12.5 pCi/g	
Construction Worker			
Ingestion of soil/sediment			
Direct external gamma exposure			
Manganese	NA	1,400 mg/kg	Maximum concentration from composite surface soil, composite soil boring, or composite sediment samples used for upper bound screening analysis.
Nickel	NA	30 mg/kg	
Am-241	NA	2.08 pCi/g	
Pu-239	NA	0.718 pCi/g	
U-234	NA	1.57 pCi/g	
U-235	NA	0.19 pCi/g	
U-238	NA	1.49 pCi/g	
Inhalation of contaminated dusts			
Manganese	1.4×10^{-3} μg/m³	2.3×10^{-3} μg/m³	Mean and 95 UCL contaminant concentrations from composite surface soil and composite soil boring used to estimate airborne contaminant concentrations.
Nickel	6.9×10^{-5} μg/m³	8.8×10^{-5} μg/m³	
Am-241	1.2×10^{-4} pCi/m³	2.8×10^{-4} pCi/m³	
Pu-239	6.7×10^{-5} pCi/m³	1.5×10^{-4} pCi/m³	
U-234	4.5×10^{-3} pCi/m³	6.1×10^{-3} pCi/m³	
U-235	2.3×10^{-4} pCi/m³	4.0×10^{-4} pCi/m³	
U-238	4.2×10^{-3} pCi/m³	5.7×10^{-3} pCi/m³	

Table 4-2
Summary of Exposure Point Concentrations
Standley Lake Diversion Project Risk Assessment

Scenario/Pathway	Exposure Concentration		Comments
	Average	Upper Bound	
Residential			
Ingestion of soil/sediment			
Direct external gamma exposure			
Manganese	NA	1,400 mg/kg	Maximum concentration from composite surface soil, composite soil boring, or composite sediment samples used for upper bound screening analysis.
Nickel	NA	30 mg/kg	
Am-241	NA	2.08 pCi/g	
Pu-239	NA	0.718 pCi/g	
U-234	NA	1.57 pCi/g	
U-235	NA	0.19 pCi/g	
U-238	NA	1.49 pCi/g	
Inhalation of contaminated dusts			
Manganese	6.9×10^{-4} μg/m³	1.2×10^{-3} μg/m³	Mean and 95 UCL contaminant concentrations from composite surface soil and composite soil boring used to estimate airborne contaminant concentrations
Nickel	3.4×10^{-5} μg/m³	4.6×10^{-5} μg/m³	
Am-241	5.1×10^{-5} pCi/m³	1.1×10^{-4} pCi/m³	
Pu-239	3.0×10^{-5} pCi/m³	6.9×10^{-5} pCi/m³	
U-234	2.2×10^{-3} pCi/m³	3.2×10^{-3} pCi/m³	
U-235	1.1×10^{-4} pCi/m³	2.0×10^{-4} pCi/m³	
U-238	2.1×10^{-3} pCi/m³	3.0×10^{-3} pCi/m³	
Recreational			
Ingestion of soil/sediment			
Direct external gamma exposure			
Manganese	NA	1,400 mg/kg	Maximum concentration from composite surface soil, composite soil boring, or composite sediment samples used for upper bound screening analysis
Nickel	NA	30 mg/kg	
Am-241	NA	2.08 pCi/g	
Pu-239	NA	0.718 pCi/g	
U-234	NA	1.57 pCi/g	
U-235	NA	0.19 pCi/g	
U-238	NA	1.49 pCi/g	

Note:

NA = Not Applicable (upper bound evaluation showed risks less than 1×10^{-6} or HI less than 1.0).

parameters. The general equation from RAGS used to estimate nonradiological chemical intake is:

$$I = C \times \frac{CR \times EFD}{BW} \times \frac{1}{AT}$$

where:

I =	intake; the amount of compound at the exchange boundary (mg/kg-day)
C =	constituent concentration (average or maximum concentration contacted over the exposure period) (e.g., mg/kg soil)
CR =	contact rate; the amount of contaminated medium contacted per unit time or event (e.g., kg/day)
EFD =	exposure frequency and duration (may be site- or activity-specific (e.g., days/year and years)
BW =	body weight (kg)
AT =	averaging time; period over which the exposure is averaged (days)

This intake formula is modified to estimate radionuclide intake as follows:

$$I = C \times IR \times EFD$$

where:

I =	activity intake (e.g., pCi)
C =	radionuclide concentration (e.g., pCi/g or pCi/m^3)
IR =	intake rate; amount of contaminated medium taken into the body per unit time (e.g., g/day or m^3/day)
EFD =	exposure frequency and duration

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Construction worker, residential and recreational intakes via ingestion of contaminated soils and direct gamma exposure are calculated under the risk screening approach using upper bound exposure parameters. The exposure duration for the construction worker and residential scenarios are assumed to be 1 year, while that for the recreational scenario is 30 years. A "hot spot" intake is calculated for the construction worker via ingestion in which the maximum concentrations from discrete surface soil boring samples are multiplied by 10.0 and used with an estimated exposure frequency of 10 days/year. A factor of 10.0 was applied to the maximum discrete surface boring concentration to provide an absolute worst-case exposure concentration for this short duration scenario.

The assumptions for soil ingestion used for this assessment include: 480 mg/day for the construction worker scenario in highly dusty conditions, 200 mg/day for the child scenario, and 100 mg/day for the adult scenario.

The assumptions for inhalation used in this assessment include: 20 m^3/day, a reasonable upper bound, for the construction worker during an 8-hr work day consisting of moderate to heavy activity; and 20 m^3/day, an upper bound daily rate for the residential receptors during various levels of activity at the home.

Receptor dust concentrations are modeled with assumptions based only on the total mass of particulate matter injected into the air over 1 year, and transport of that total mass under average annual meteorological conditions. This results in an annual average total dust concentration at each receptor location. These annual average concentrations do not reflect the potential time variations of the dust concentrations. Under actual work conditions construction workers (and nearby residents) would be expected to be exposed to an average dust concentration during the work day. Exposures would drop to zero at night and on weekends since no dust generating activities are occurring (and the worker is not at the site). Because it was not possible to generate an average dust concentration covering just the work day, these exposure conditions were simulated using annual average dust concentrations. Because annual average concentrations were used, a construction worker exposure frequency of 350 days/yr must also be used for inhalation exposures. Assuming that a worker is exposed continuously (350 days/yr) to an annual average dust concentration should be a reasonable approximation of intake from actual work day exposures. The annual average dust concentration (and exposure frequency of 350 days/yr) takes into account the reduction in dust concentrations during non work hours, just as would be accomplished using a work day average dust concentration, with a shorter (250 days/yr) exposure frequency. This approach should result in conservative overestimates of intake because it implicitly assumes that the receptor is at the site 24 hr/day; no explicit reduction in intake is assumed because of time spent indoors.

While the construction work day is estimated to be 10 hr, the 20 m^3/day inhalation rate for construction workers is considered appropriate. This is a reasonable upper bound value for moderate to heavy activity during an 8-hr work day. This is a fairly high intake rate and probably represents a close approximation to the total 24-hr inhalation rate. Annual average concentrations coupled with a 20 m^3/day inhalation rate and an exposure frequency of 350 days/yr, will most likely result in overestimates of intake: furthermore, this method does not account for periods of natural wet conditions in which dust generation would be negligible, therefore overestimating intake.

Table 4-3 shows a summary of the exposure parameters and assumptions used in estimating intake for the construction worker, construction hot spot, residential, and recreational scenarios. Intake calculations for both chemicals and radionuclides of concern are found in the Appendix B with the risk calculations.

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Table 4-3

Proposed Exposure Assessment Scenarios and Parameters for the Standley Lake Diversion Project Risk Assessment

Exposure Parameter	Scenario			
	Construction Hot Spot	**Construction**	**Residential**	**Recreational**
Dust Concentration	NA	Based on air modeling. Annual average concentration and 95 percent UCL concentration.	Based on air modeling. Annual average concentration and 95 percent UCL concentration.	NA
Soil Concentration	Ten times the maximum concentration from discrete sample results (non-composited top portion of borehole sample SB-0.5).	Maximum constituent concentration from composite surface soil, composite soil, boring, or composite sediment samples used for screening analyses. Average and 95 percent UCL used for inhalation and ingestion intake calculations when screening risks $>1 \times 10^{-6}$.	Maximum constituent concentration from composite surface soil, composite soil boring, or composite sediment samples used for screening analyses. Average and 95 percent UCL used for inhalation and ingestion intake calculations when screening risks $>1 \times 10^{-6}$.	Maximum constituent concentration from either composite surface soil, composite soil boring, or composite sediment samples used for screening analyses of ingestion and external gamma exposure calculations.
Airborne Contaminant Concentration	NA	Average dust concentration × average surface soil composite or soil boring composite concentration, and 95 percent UCL dust concentration × 95 percent UCL surface soil composite or soil boring composite concentration.	Average dust concentration × average surface soil composite or soil boring composite concentration, and 95 percent UCL dust concentration × 95 percent UCL surface soil composite or soil boring composite concentration.	NA
Inhalation Rate	NA	20 m^3/day[a]	20 m^3/day[b] (adult) 15 m^3/day (child)	NA
Soil Ingestion Rate	480 mg/day[c]	480 mg/day[c]	200 mg/day child[d] 100 mg/day adult	200 mg/day child[d] 100 mg/day adult
Body Weight	70 kg	70 kg	70 kg	70 kg
Exposure Frequency	10 days/year[b]	250 days/year[e] (Inhalation = 350 days/year)	350 days/year[e]	60 days/year[b]
Exposure Duration	One year	One year	One year	6 years (child) 24 years (adult)

Table 4-3
Proposed Exposure Assessment Scenarios and Parameters for the Standley Lake Diversion Project Risk Assessment

	Scenario			
Exposure Location	Construction area	Construction area. See Figure 4-2 for receptor locations for inhalation.	Residential areas adjacent to construction area. See Figure 4-2 for receptor locations for inhalation.	Recreational areas adjacent to diversion canal route

[a]Worker inhalation rate = 20 m^3/day over an 8-hr work day [Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-03].
[b]Residential inhalation rate = 20 m^3/day, 24 hr per day (Exposure Factors Handbook, EPA, 1990a).
[c]Incidental soil ingestion rate = 480 mg/day for outdoor occupations in potentially dusty conditions, OSWER Directive 9285.6-03.
[d]Incidental soil ingestion rate = 200 mg/day for child 1 to 6 years of age, 100 mg/day age 6 years and greater (Exposure Factors Handbook, EPA, 1990a).
[e]Construction duration expected to be approximately one year.
[f]OSWER Directive 9285.6-03.
[g]OSWER Directive 9285.6-03.
[h]Exposure frequency based on site-specific conditions and professional judgment.

Note:

NA = Not Applicable.

Section 5

Risk Characterization

Risk characterization is a summation of information developed out of the data evaluation, exposure assessment, and the toxicity assessment. This section describes the approach used to develop the human health risk estimates and presents a quantitative risk characterization of exposure to the contaminants of concern via ingestion of contaminated soils, inhalation of contaminated particulates, and direct exposure to gamma radiation during construction of the SLDP.

Risk is a function of exposure and toxicity. A risk screening approach was used as part of the SLDP risk assessment for certain pathways that present minimal potential risks. The screening assessment involved estimating exposures (intake) to receptors using maximum detected concentrations of the chemicals of concern, as described in the exposure assessment. For pathways that present higher potential risks (such as inhalation), intakes were calculated using average and 95 percent UCL on the mean concentrations of the chemicals and radionuclides of concern. The toxicities of the contaminants of concern were then evaluated for their potential adverse health effects and potency, as described by applicable EPA-derived cancer SFs or RfDs. The exposure estimates were compared or combined with these toxicity values to generate a quantitative risk estimate.

For pathways where maximum screening assumptions resulted in risks less than 1×10^{-6}, no further analyses were conducted, and maximum screening risks were shown in the summary tables under "upper bound" risks. For pathways with maximum screening risks greater than 1×10^{-6}, risks were reevaluated using average and 95 percent UCL exposure assumptions. The summary tables show these risks under average and upper bound exposure categories, respectively.

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5.1 Risk Characterization Methods for Nonradiological Contaminants of Concern

5.1.1 Noncancer Risk Estimation Method

Risks associated with exposures to noncarcinogenic chemicals are estimated by comparing the predicted level of exposure to the RfD. The RfD is an estimate for daily exposure over a lifetime to a particular chemical that is likely to be without deleterious effects (EPA, 1989a). The ratio of exposure (in mg/kg-day) to the RfD (mg/kg-day) is termed the hazard quotient (HQ):

$$\text{Hazard Quotient} = \text{Exposure/RfD}$$

The basic assumption for a HQ is that a threshold exists for exposures to noncarcinogenic chemicals. When a HQ for a chemical exceeds its prescribed threshold (i.e., exceeds unity), there is concern of increased likelihood of a noncancer adverse health effect. While RfDs generally have large, but varying margins of safety built into them, exceeding unity is the point at which the EPA assumes that noncancer health effects most likely may be seen. To assess the potential for noncancer effects posed by exposures to multiple chemicals, a "hazard index" (HI) approach is used according to EPA guidance. This approach assumes additivity and does not account for synergetic or antagonistic effects. When the aggregate sum of HQs exceeds unity, the potential for health effects exists only if the chemicals act by the same toxicological mechanism.

5.1.2 Cancer Risk Estimation Methods

The potential for the incidence of cancer effects is evaluated by estimating excess lifetime cancer risk (ELCR). ELCR is described as the incremental probability of an exposed individual developing some form of cancer over one's lifetime beyond the background probability of developing cancer (i.e., if no exposure to site chemicals occurs). For

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example, a 2×10^{-6} ELCR means that, for every 1 million people exposed to a particular carcinogen throughout their lifetimes, the average incidence of cancer may increase by two cases of cancer. The background probability of developing cancer is about one in four. An ELCR range of 1×10^{-4} to 1×10^{-6} is generally used by EPA to manage risks.

As previously discussed, the potency of carcinogenic chemicals is reflected in their EPA-derived cancer SFs. These values represent upper bound estimates, so any cancer risks generated in this risk assessment should be regarded as upper bound estimates on the potential incidence of cancer rather than true cancer risks. The true cancer risk is likely to be less than that predicted (EPA, 1989).

The SF converts an estimated lifetime daily intake to an ELCR. As such, risk is directly proportional to intake. This relationship is depicted by the following equation:

$$\text{Risk} = \text{Cancer Slope Factor} \times \text{Exposure (or Intake)}$$

As with noncancer effects, synergistic or antagonistic interactions are not accounted for in exposures to multiple cancer-causing chemicals. Cancer risks associated with a similar exposure route are therefore considered additive. This is consistent with the current EPA guidelines on multiple chemical exposures (EPA, 1989).

5.2 Radiological Dose and Risk Assessment Methods

The methods used for the radiological risk assessment conform to the guidelines outlined in Chapter 10 of the *Risk Assessment Guidance for Superfund, Volume I: Health Evaluation Manual, Part A* (EPA, 1989b). The following subsections discuss assumptions and methods for internal and external radiation exposure assessments used to determine risks related to exposure to the radiological contaminants of concern for the SLDP.

5.2.1 Internal Exposure

Internal exposure to radiation may occur through inhalation or ingestion of radioactive contaminants. Determination of risk due to internal exposure involves calculating the total amount of radioactive material taken into the body and then applying an intake to risk conversion factor. These risk (or slope) factors have been developed largely from studies of human exposure to radiation. The radiological risk factors developed from these studies account for the movement of radionuclides in the body, including organ-specific uptake and retention characteristics; decay of parent radionuclide and production or radioactive daughter products; and relative sensitivities of different organs to radiation exposure. The risk of cancer incidence from internal exposure to radiological contaminants was determined using the risk factors published in the first quarter 1992 Health Effects Assessment Summary Tables (HEAST) (EPA, 1992). The following paragraphs describe the methods used for determining each of the parameters shown in the risk calculation spreadsheets for radionuclides (Appendix B).

The dose conversion factors (DCFs) used for calculating dose are taken from *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (EPA, 1988e). These DCFs are used to determine the committed effective dose equivalent (CEDE) resulting from intake of each radionuclide. The "committed dose" concept was introduced as a means of controlling occupational exposures to radionuclides that remain in the body for long periods of time.

DCFs are listed by solubility class and lung clearance class for each radionuclide. Solubility classes are characterized by an "F1" value. The F1 value represents the fraction of the radiological contaminant that is transferred from the gastrointestinal system to the blood. The F1 and lung clearance class values for a particular radionuclide are

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dependent on the chemical form of that radionuclide. In most cases for this assessment, DCFs and risk factors were chosen using default F1 values and lung clearance classes from the HEAST or NESHAPS documentation. These default values represent the most conservative (worst-case) situation. For other chemical forms, the doses and risks would be lower.

The CEDE (1-year intake) as used in this report is the total dose equivalent resulting over a 50-year period from an intake of radioactive material over a 1-year period. This value is reported in units of mrem/year to show that it is the CEDE resulting from 1 year of intake. This is distinguished from the next column in the risk-calculation tables, which shows the total CEDE in mrem resulting from the accumulated intakes over the entire exposure period.

The total CEDE represents the sum of each 50-year CEDE accumulated over the exposure duration. This value is determined by multiplying the CEDE resulting from 1 year of intake by the number of years of intake. It may also be determined by multiplying the total intake by the appropriate DCF. The total CEDE, as shown in the risk calculation tables, will tend to overestimate doses for the radionuclides with long retention times in the body (Pu-239). Because the exposure duration for the construction and residential scenarios is 1 year, the total and annual CEDE values are the same.

As with chemical contaminants, the risk of cancer incidence from ingesting or inhaling radioactive contaminants is determined by multiplying the total lifetime radionuclide intake by the cancer-incidence risk factor for ingestion or inhalation. This relationship is shown by the following equation:

$$\text{Risk} = \text{Cancer Risk Factor (Risk/pCi)} \times \text{Radionuclide Intake (pCi)}$$

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5.2.2 External Exposure

Doses and risks from external exposure to gamma radiation were determined using ground surface external gamma dose and risk conversion factors. These factors convert surface soil concentrations in pCi/g to dose rate in mrem/year or risk (risk/year) to an individual standing on the surface of a large, uniformly contaminated area. Surface soil dose factors were taken from NUREG/CR-5512, *Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Dose*, Draft Report for Comment, January 1990. Ground surface risk factors were taken from the January 1992 HEAST (EPA, 1992). Surface soil external gamma risk factors are calculated in units of risk/year per pCi/g. These factors were modified where appropriate by a factor T_e representing the fraction of the year that an individual could be exposed to external gamma radiation. This fraction was calculated as shown below:

$$T_e = ET \times EF/8{,}400$$

where:

T_e =	fraction of year exposed to gamma radiation
ET =	exposure time (hr/day)
EF =	exposure frequency (day/year)
8,400 =	number of hours in a year assuming exposure for 24 hr/day for 350 days

External risk calculations also incorporated a shielding factor of 0.2 for residential exposures (EPA, 1991b). This allows for a reduction of external radiation exposure by 20 percent due to shielding from structures while indoors.

The following equation is used for calculating risks from external gamma exposure:

$$\text{Risk} = SC \times ED \times T_e \times (1 - SF) \times ERF$$

where:

SC =	soil concentration (pCi/g)
ED =	exposure duration (year)
T_e =	fraction of year exposed
SF =	shielding factor (unitless)
ERF =	external gamma risk factor (risk/year per pCi/g)

5.3 Risk Estimates

The following sections provide estimates of risk for each of the major potential exposure scenarios associated with construction of the SLDP.

5.3.1 Construction Scenario

Under the construction worker scenario, workers could be exposed to contaminants through ingestion of soils and sediments, inhalation of dust (from soils), or direct external exposure to gamma radiation from radionuclides in soils or sediments. This scenario assumes that a receptor is exposed to constituents of concern throughout the exposure duration, regardless of variations in work locations, activities, etc. Maximum concentrations of contaminants from composite surface soil, composite soil boring, and sediment samples were used to perform a screening assessment of upper bound construction worker risks through the ingestion and external gamma exposure pathways. Use of maximum sample results, without regard for the location of the maximum, provides a conservative (high) estimate of risks from these pathways. For pathways with upper bound screening, cancer risk greater than 1×10^{-6} or an HI greater than 1.0, an average or "typical" risk value was also calculated. A summary of chemical and

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radiological risks associated with the construction scenario is shown on Table 5-1. Risk calculations for the construction ingestion, inhalation, and external gamma exposure pathways are provided in Appendix B.

For chemical exposures, the ingestion pathway HI for the upper bound exposure evaluation is estimated to be 0.07. This risk estimate is primarily from ingestion of manganese in soils. This risk is estimated to be the highest to which a construction worker would potentially be subject to, given the exposure parameters used in estimating intake. No ELCR is estimated for this route of exposure because both manganese and nickel are not considered carcinogens via ingestion. The HI is less than unity, suggesting that exposures under this scenario will most likely not lead to adverse health effects.

Upper bound screening radiological risks from ingestion and external gamma exposure are 9×10^{-8} and 3×10^{-8}, respectively, well below the lower end of the acceptable risk range. The primary contributors to risk from ingestion are Am-241 and Pu-239. For external gamma exposure, the primary contributors to risk are U-234, U-238, and their associated decay products.

Risks associated with the inhalation pathway were evaluated for typical (average) and upper bound worker exposure conditions. For the analysis of average risk from inhalation of contaminated dust, average soil sample results (surface soil and soil boring) and the average of the modeled dust concentrations for construction receptors were combined to determine an average airborne contaminant concentration. To determine the upper bound airborne contaminant concentration, the 95 percent UCL surface soil and soil boring sample concentrations were combined with the 95 percent UCL modeled dust concentration..

The inhalation pathway chemical ELCR estimated for the construction worker under the upper bound exposure conditions is 3×10^{-7}, due to intake of nickel in contaminated dust. The inhalation pathway HI is estimated to be 0.46, resulting from inhalation of

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Table 5-1
Summary of Risk Estimates for the Construction Exposure Scenario

Pathway	Chemical				Radiological	
	Average Exposure		Upper-Bound Exposure		Average Exposure	Upper-Bound Exposure
	Excess Cancer Risk	Hazard Index	Excess Cancer Risk	Hazard Index	Excess Cancer Risk	Excess Cancer Risk
Ingestion	NA	a	NA	0.07	a	9×10^{-8}
Inhalation	2×10^{-7}	0.28	3×10^{-7}	0.46	2×10^{-6}	3×10^{-6}
External Exposure	NA	NA	NA	NA	a	3×10^{-8}
Total	**2×10^{-7}**	**0.28**	**2×10^{-7}**	**0.53**	**2×10^{-6}[b]**	**3×10^{-6}**
Major Contributors to Total Pathway Risk	Nickel	Manganese	Nickel	Manganese	U-234, U-238	U-234, U-238

[a]Risks for average exposure not calculated since upper bound risks less than 10^{-6} or upper bound HI less than 1.0.
[b]Upper bound risks for ingestion and external exposure included in total for average exposure.

Note:

NA = Not Applicable.

manganese in soils. These same risk estimates under average exposure conditions are 2×10^{-7} and 0.28, respectively.

For inhalation of contaminated dust, radiological risks to the construction worker ranged from an average of 2×10^{-6} to an upper bound of 3×10^{-6}. The primary contributors to risks from inhalation of radionuclides are U-234 and U-238. Pu-239 and Am-241 combined contribute only approximately 3 percent of the risk for the upper bound case and 2 percent of the risk for the average case. Uranium concentrations are summarized below for the inhalation risk analysis:

Uranium Concentration (pCi/g)				
	Surface Soil		Subsurface Soil	
	Average	95 Percent UCL	Average	95 Percent UCL
U-234	1.09	1.3	1.05	1.3
U-235	0.06	0.12	0.05	0.09
U-238	1.06	1.24	0.98	1.25

These uranium concentrations are well within the ranges of reference natural background concentrations for the Rocky Mountain region (shown in Table 2-8). In addition, there is very little variation between surface soil and subsurface soil results for each of the uranium isotopes. This suggests that the uranium concentrations are due to naturally occurring uranium and not from airborne deposition from the RFP. Also, natural uranium consists of approximately 50 percent U-234 and 50 percent U-238 by activity. The close correlation between U-234 and U-238 results, both in the surface and subsurface soils, is further evidence that these uranium concentrations are representative of natural uranium concentrations in this area. Finally, the close correlation between average and 95 percent UCL values for each of the uranium isotopes indicates that there is a fairly tight distribution of concentrations for each isotope. If this area had been impacted by significant areal deposition of uranium through releases from the RFP, a much wider distribution would be expected due to the presence of localized "hot spots."

5.3.2 Construction "Hot Spot" Scenario

Under the construction "hot spot" scenario, workers could be exposed for up to two weeks to a discrete area of elevated contaminant concentrations. Because hot spots by definition are small and would not contribute significantly to airborne contaminant concentrations, the potential exposure routes include only ingestion and external gamma exposure.

The sampling plan for the SLDP included discrete boring samples from 0 to 0.5 ft bls (SB-0.5) to evaluate the potential for "hot spots." These samples were taken in locations determined by the sampling team to be likely areas for increased deposition (e.g., behind small hills, etc.). However, it is possible that hot spots exist that were not sampled. For this reason, the maximum discrete boring sample results were multiplied by 10.0 to provide a very conservative estimate of potential hot spot concentrations.

A summary of construction hot spot scenario risks is shown in Table 5-2. Risk calculations for the construction "hot spot" scenario are provided in Appendix B.

The ingestion pathway upper bound chemical HI estimated under the construction "hot spot" scenario is below unity, 0.01. Construction hot spot risks are 1×10^{-8} for ingestion of radionuclides and 8×10^{-9} for external gamma exposure. The primary contributors to risk are Pu-239 for ingestion and U-238 for external gamma exposure.

5.3.3 Residential Scenario

The residential exposure scenario includes exposure to contaminants through ingestion of contaminated soils, inhalation of contaminated dusts, and direct external exposure to gamma radiation. As with the construction scenario, maximum concentrations from composite surface soil, soil boring, and sediment samples were used to perform a

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Table 5-2
Summary of Risk Estimates for the Construction "Hot Spot" Exposure Scenario

Pathway	Chemical		Radiological
	Upper-Bound Exposure		Upper-Bound Exposure
	Excess Cancer Risk	Hazard Index	Excess Cancer Risk
Ingestion	--	0.01	1×10^{-8}
Inhalation	NA	NA	NA
External Exposure	NA	NA	8×10^{-9}
Total		**0.01**	**2×10^{-8}**
Major Contributors to Risk		Manganese	Pu-239, U-238

NA = Not applicable for this pathway.

screening assessment of the ingestion and direct external gamma exposure routes. A summary of chemical and radiological risks associated with residential exposures is shown in Table 5-3. Chemical and radiological risk calculations for the residential exposure scenario are shown in Appendix B.

The upper bound residential ingestion pathway chemical HI is 0.02, below unity. Risk estimates were not calculated for this scenario under more average exposure parameters because the risks would be lower than those estimated for the upper bound exposure, which are below levels of concern.

The upper bound risk from ingestion of maximum concentrations of radionuclides in soils or sediments is 3×10^{-8}. The primary contributor to ingestion risks is Pu-239. The upper bound risk from exposure to direct external gamma radiation from soils or sediments containing maximum radionuclide concentrations is 9×10^{-8}. The primary contributors to external gamma risk are U-235 and U-238 and their decay products.

Residential risks from inhalation of contaminated dusts were determined using the same methods used for the construction inhalation scenario. Modeled dust concentrations averaged over the residential receptor points were used with average soil contaminant concentrations to develop average airborne contaminant concentrations. Similarly, 95 percent UCL dust concentrations were used with 95 percent UCL soil contaminant concentrations to develop upper bound airborne contaminant concentrations.

The upper bound risk estimates for the nearby resident include an inhalation pathway chemical ELCR of 2×10^{-7} and an inhalation pathway HI of 0.24. Those estimated under average exposure conditions include an ELCR of 1×10^{-7} and a HI of 0.14.

Risks to residential receptors from inhalation of radiological contaminants ranged from an average of 1×10^{-6} to an upper bound of 2×10^{-6}. As with the construction scenario, the inhalation risks were associated primarily with background concentrations of naturally occurring U-238 and U-234.

Table 5-3
Summary of Risk Estimates for the Residential (Adult) Exposure Scenario

Pathway	Chemical				Radiological	
	Average Exposure		Upper-Bound Exposure		Average Exposure	Upper-Bound Exposure
	Excess Cancer Risk	Hazard Index	Excess Cancer Risk	Hazard Index	Excess Cancer Risk	Excess Cancer Risk
Ingestion Inhalation External Exposure	[a] 1×10^{-7} NA	[a] 0.14 NA	-- 2×10^{-7}	0.02 0.24	[a] 1×10^{-6} [a]	3×10^{-8} 2×10^{-6} 9×10^{-8}
Total	**1×10^{-7}**	**0.14**	**2×10^{-7}**	**0.26**	**1×10^{-6}[b]**	**2×10^{-6}**
Major Contributors to Total Pathway Risk	Nickel	Manganese	Nickel	Manganese	U-234, U-238	U-234, U-238

[a]Risks for average exposure not calculated since upper bound risks less than 10^{-6}, or upper bound HI less than 1.0.
[b]Upper bound risks for ingestion and external exposure included in total for average exposure.

Note:

NA = Not Applicable.

5.3.4 Future Recreational Scenario

Potential long-term exposures to chemical and radiological contaminants were evaluated using a future recreational exposure scenario. This scenario includes exposures through ingestion of contaminated soils and sediments and direct external exposure to gamma radiation. Because areas disturbed during construction of the SLDP will be revegetated, inhalation of contaminated dusts is not considered an exposure pathway for the future recreational scenario. As with the ingestion and direct external pathways under the residential scenario, a screening analysis was performed using the maximum detected concentrations of each contaminant in surface soil composite, soil boring composite, and sediment (composite) samples. This scenario assumes that individuals could be exposed through direct external gamma exposure and ingestion of contaminated soils containing maximum contaminant concentrations during recreational activities after construction of the SLDP canal.

Under the future recreational scenario, it is assumed that an individual could be exposed primarily during the summer months. An exposure time of 2 hr/day, exposure frequency of 60 days/year, and exposure duration of 30 years were used for the recreational screening analysis. Recreational scenario risks are summarized in Table 5-4. Risk calculations for the recreational scenario are shown in Appendix B.

The ingestion pathway HI estimate under the recreational upper bound exposure conditions is 0.005, primarily from ingestion of manganese in soils. Upper bound radiological risks from future recreational exposures range from 5×10^{-8} for external gamma exposure to 2×10^{-7} for ingestion of contaminated soil or sediment. The primary contributors to recreational risks are U-238 and U-235 (and their associated decay products) for external gamma exposures and Am-241 and Pu-239 for ingestion of contaminated soils.

Table 5-4
Summary of Risk Estimates for the Recreational Exposure Scenario

	Chemical		Radiological
	Upper Bound Exposure		Upper Bound Exposure
Pathway	Excess Cancer Risk	HI	Excess Cancer Risk
Ingestion		0.005	2×10^{-7}
Inhalation	NA	NA	NA
External Exposure	NA	NA	5×10^{-8}
Total		**0.005**	$\mathbf{3 \times 10^{-7}}$
Major Contributors to Risk		Manganese	Am-241 Pu-239

5.3.5 Deposition Analysis

As part of the air modeling process, deposition rates were determined for each of the residential receptor locations. The modeled deposition rates at each receptor location are shown in Appendix C. In order to determine if deposition of contaminated dust could result in significant increases in contaminant concentrations in soil at residential receptor locations, a deposition analysis was performed. The deposition analysis consisted of a screening evaluation of maximum contaminant deposition rates for each contaminant of concern, and estimation of upper bound soil contaminant concentrations caused by deposition. Maximum areal deposition rate for each contaminant of concern was determined by combining the maximum surface soil contaminant concentration with the maximum surface soil deposition rate, and the maximum subsurface soil contaminant concentration with the maximum subsurface soil deposition rate. This contaminant deposition rate was multiplied by the deposition time (1 year) to determine total areal contaminant concentration (pCi/m^2 or $\mu g/m^2$). Areal contaminant concentrations were then converted to estimates of soil concentration using a soil density of 1.43 g/cm^3 and a depth of 1 cm. This analysis assumes that deposition would only impact soil concentrations to a depth of approximately 1 cm. This is based on professional judgment and should result in overestimates of soil concentrations resulting from deposition. Deeper depths would result in lower contaminant soil concentrations.

The results of the deposition analysis are shown in Table 5-5. Estimated chemical concentrations resulting from the deposition of contaminated dust are much less than the current mean concentrations. Assuming that deposition of particulates generated during construction activities results in concentrations of manganese and nickel of 162 mg/kg and 6.6 mg/kg, respectively; the corresponding HQs are 0.003 and 0.0005, respectively. These risk estimates represent a 30-year exposure to these chemicals via ingestion of soils. Estimated radionuclide concentrations caused by deposition of contaminated dust (from soil contaminated to maximum contaminant levels) are much less than the concentrations currently present in the soil. The estimated soil concentrations from

Table 5-5
Summary of Estimated Soil Contaminant Concentrations Resulting from Deposition

Constituent	Concentration	
	(μg/g)	(pCi/g)
Manganese	0.162	
Nickel	0.0066	
U-234		0.35
U-235 and daughters		0.028
U-238 and daughters		0.31
Pu-239		0.012
Am-241		0.016

deposition result in incremental risks of 3×10^{-8} from ingestion and 4×10^{-7} from external exposures under a maximum residential (30-year) exposure scenario. The risk calculations from deposition are shown in Appendix B.

5.3.6 Evaluation of Radiological Risks to Children

Because established radiological dose and risk factors are age-averaged and sex-averaged, it is difficult to directly evaluate the risks associated with radiation exposures only during childhood years. A qualitative estimate of radiological risks to children may be made using data from EPA's *Risk Assessments Methodology, Environmental Impact Statement, NESHAPS for Radionuclides, Background Information Document—Volume 1* (EPA/520/1-89-005). This background information document contains information on age-specific cancer incidence risk per unit dose for five age groups, for both males and females. Table 5-6 shows a summary of age-specific cancer incidence risk for combined males and females.

A comparison of age-specific cancer incidence risk per unit dose for ages 0 through 9 (male and female) with the cancer incidence risk per unit dose for all ages (male and female) shows that risks from exposure at ages 0 through 9 are approximately 1433.5×10^{-6} cancers per rad, compared to 622.96×10^{-6} cancers per rad for the average risk over all ages. Thus, risks from exposure at ages 0 through 9 are approximately 2.3 times higher than the age-averaged, sex-averaged cancer incidence risk per unit dose. Since the cancer incidence per unit dose rates shown in Table 5-3 form the basis for EPA's cancer incidence risk per unit intake factors in HEAST, the age-specific relationship should also apply to the HEAST factors. Therefore, a qualitative estimate of risk to children (ages 0 through 9) may be made by multiplying the HEAST risk factors for radionuclides by 2.3.

Approximate risks to children have been derived by taking the risks from the residential scenario discussed in Section 5.2.4 and scaling them up based on differences in intake

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Table 5-6 Site-Specific Incidence Risk Per Unit Dose (1.0E-6 per rad) for Combined Leukemia-Bone and Constrained Relative Risk Model						
	Age at Exposure					
Site	**0-9**	**10-19**	**20-34**	**35-49**	**50+**	**All**
Leukemia	77.69	34.26	48.06	31.39	41.20	44.76
Bone	3.09	3.06	2.99	2.72	1.58	2.50
Thyroid	122.24	113.32	82.26	50.66	16.05	64.28
Breast	387.78	389.82	102.42	47.18	14.74	141.95
Lung	120.19	120.88	98.24	67.02	25.44	74.54
Esophagus	23.56	23.71	6.22	3.14	2.16	9.09
Stomach	139.95	140.71	60.00	25.25	13.20	60.08
Intestine	103.38	103.92	41.03	16.00	8.74	42.86
Liver	142.55	142.30	36.17	10.71	2.67	49.55
Pancreas	97.71	98.30	30.85	12.73	7.60	38.23
Urinary	105.58	106.08	40.02	17.68	6.37	42.82
Lymphoma	53.21	53.07	14.26	4.20	1.02	18.69
Other	56.55	56.31	50.43	21.33	11.19	33.60
Total	1,433.50	1,385.70	612.96	310.01	151.96	622.96

and age-specific cancer factors discussed above. For ingestion of soils, a child to adult scaling factor of 4.6 (2×2.3) was applied because children ingest soil at approximately 2 times the adult rate (0.2 mg/day for children age zero to 6, compared to 0.1 mg/day for adults). Ingestion risks to children are thus approximately 1×10^{-7} under the maximum residential exposure scenario.

For direct external gamma exposure, adult residential risks were multiplied by 2.3 to approximate risks to children. This results in a maximum estimated child risk of 2×10^{-7} risk from external gamma exposure.

For inhalation of soils, residential average and residential maximum risks were multiplied by a scaling factor of 1.73. This factor is based on the differences in child and adult inhalation rates (15 m^3/day divided by 20 m^3/day) and the increased risk factor of 2.3 ($15/20 \times 2.3$). An approximate inhalation risk to children is thus 2×10^{-6} for the average case and 3×10^{-6} for the upper bound case. As with the residential inhalation risks, child inhalation risks are primarily associated with background concentrations of naturally occurring uranium.

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Section 6

Evaluation of Uncertainties

This section discusses the key assumptions and uncertainties that affect the level of confidence placed on the quantitative risk estimates derived for the SLDP risk assessment. Because uncertainties are inherent in any risk assessment, a qualitative discussion of these uncertainties helps put into perspective the risks calculated for the site. The discussion focuses on the main sections of the risk assessment:

- Data evaluation
- Toxicity assessment
- Exposure assessment
- Risk characterization

6.1 Uncertainties in the Data Evaluation

Of the variables used in performing the risk assessment, the error terms related to the laboratory analyses are probably the best defined and, in some cases, provide less uncertainty than other factors in the assessment. While individual errors or biases in analytical procedures are possible, performing an objective evaluation of the data serves to limit the use of questionable results.

The primary data limitations and uncertainties associated with concentration estimates and data at the site and the potential effect on the quantitative risk assessment include the following observations:

- The size of the database is relatively small, thus increasing uncertainty in characterizing the extent of potential contamination. While composite

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samples were collected that serve to increase areal coverage, they may have a diluting effect on actual concentrations at specific points. This may serve to underestimate risk in that the use of such data may result in an underestimation of intake.

- For nonradiological constituents, data flagged with laboratory concentration and quality qualifiers were used as proxy concentrations in calculating a mean and 95 percent UCL on the mean. While the use of such data is appropriate for a quantitative risk assessment, a certain degree of uncertainty results that may underestimate or overestimate risk.

- Comparing metal and radionuclide concentrations to broad, regional background values may cause uncertainty in that actual, site-specific background concentrations may be above or below these values.

6.2 Uncertainties in the Toxicity Assessment

Much of the data describing carcinogenic and noncarcinogenic effects of chemicals is from experimentation using animal models or from limited human epidemiological or clinical studies. While various physiological and biochemical similarities exist between some animal species and humans, it is generally accepted that a response seen in animals may also occur in humans under similar exposure conditions. However, when extrapolating data from animal models, toxicity values are derived using uncertainty factors and modifying factors as added margins of safety.

Estimating carcinogenic effects involves the use of a linearized multistage model to predict cancer induction at very low doses. While this procedure is consistent with some proposed mechanisms of carcinogenesis, such an estimate may provide an unrealistic prediction of risk. The true value of risk is unknown and may be as low as zero.

The toxicity values used are generally based on chronic or lifetime exposures. The exposures assessed during the construction phase of the SLDP are subchronic. Also, use of chronic-toxicity factors for subchronic exposures to a child receptor is overly conservative because of differences in exposure durations. Using these value may tend to overestimate risk.

To assess the overall potential for cancer and noncancer effects posed by multiple chemical exposure, cancer risks or hazard indices are summed. This method may be conservative since it does not take into account potential differences in toxic end points.

A high degree of certainty can be shown between high radiation doses and effects on humans. Much less certainty exists for the effects from low doses of radiation. The cancer risk coefficients are based on extrapolation of high-dose human data to low doses expected from environmental exposures. Although this approach is better than using animal-derived data, it still leads to uncertainty. The uncertainty is also influenced by other factors such as differences in the quality (LET) and type of radiation, total dose, dose distribution, dose rate, and radiosensitivity (including repair mechanisms, variations in age, state of health, target organ, and gender). The BEIR V Committee evaluated uncertainty in their cancer risk estimates. Although the BEIR V Committee increased the risk estimates for radiation-induced cancer, they also acknowledged that the uncertainty associated with these estimates is large enough that at low doses (comparable to background), the risk of cancer induction may be zero. Table 3-3 presents ranges for most of the risk factors used to assess exposure risk to radiation. The magnitudes of variability in these ranges indicate the uncertainty in the risk of each radiation-induced effect.

6.3 Uncertainties in the Exposure Assessment

6.3.1 Exposure Scenario Assumptions

Offsite residential and recreational exposure scenarios identified in this assessment are assumed to reasonably reflect exposures to this population. Worker exposures to surface and subsurface soils may accurately reflect conditions at the SLDP construction site due to work activities in direct contact with potentially contaminated soil. However, a larger degree of uncertainty is associated with the offsite resident exposure scenario in terms of potential direct contact. While the proposed canal will be constructed near current residents, it is assumed that direct contact with potentially contaminated soils may occur. This assumption, however, is based on the fact that residents must be present in the construction zone for contact to occur. This may not actually occur, as dangers are inherent in any construction area and nonworkers are encouraged to stay away, although access after working hours will most likely not be monitored. Further, it is assumed that contact with soils will occur daily over the entire estimated duration of construction (one year). Given the varying climatic conditions that may exist over the period of construction, this assumption may greatly overestimate contact for both the construction worker and resident exposure scenarios.

6.3.2 Exposure Point Concentration Assumptions

Maximum exposure point concentrations were assumed to be uniformly spread throughout the entire construction zone for upper bound screening calculations. This is likely not true because concentrations of constituents can vary from area to area. Thus, this assumption may lead to overestimating intake via ingestion and direct external gamma exposure.

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Ninety-five percent UCLs on the mean concentrations were also used as exposure point concentrations for the inhalation exposure pathway. These concentrations may not represent onsite constituent concentrations, but rather overestimate such concentrations.

Average annual dust concentrations at each receptor point were used to determine average and 95 percent UCL dust concentrations generated during construction activities. This may lead to overestimates of intake of respirable particulates contaminated with constituents of concern since receptors are assumed to be in the area 24 hr/day.

6.3.3 Exposure Parameters

As previously discussed, the exposures assumed for this risk assessment are most likely overestimated. These overestimations will lead to potentially inflated risk estimations. Below is a discussion of the specific exposure parameters used in this assessment.

6.3.3.1 Ingestion

The soil ingestion rates used in estimating intake of constituents may not accurately depict conditions in which soil ingestion occurs. While these rates are based on carefully conducted experimentation, actual incidental ingestion of soil is dependent on many factors, such as personal care and hygiene. Further, it is assumed that 100 percent of the total amount of soil ingested per day is from the potentially contaminated soils within the construction corridor. For residential receptors incidental soil ingestion may occur in areas far removed from the construction corridor, thus overestimating constituent intake.

6.3.3.2 Inhalation

The inhalation pathway assumes that no controls to mitigate dust generation will be applied during construction activities. Generally, construction areas are wetted prior to

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scraping, digging, etc., to limit and prevent nuisance dust conditions. Therefore, estimates of intake via inhalation may be overestimated.

Inhalation of contaminated particulates is assumed to occur over an entire 24-hr period, even though construction activities will only generate dust during 10 hr of the day. This assumption greatly increases the estimates of intake; however, this assumption was required because of the use of average annual average dust concentrations. The annual average dust concentration is assumed to be a reasonable estimate of the 24-hr average dust concentration at each receptor point.

While the construction worker is involved in work-related activities during approximately 10 hr per day, it is assumed that respiration during these hours is equivalent to the amount respired over a 24-hr period. Also, for the resident receptor, it is assumed that contact to contaminated dust indoors is equivalent to outdoor concentrations. This intuitively is not a correct assumption, although use of an annual average tends to account for those (non-construction) periods with low dust concentration. Further, residents would be expected to spend a much larger percentage of time inside the home, particularly during the non-summer months; therefore, outdoor exposure is somewhat limited. These conservative assumptions overestimate intake and lead to potentially high risk estimates.

Inhalation represents the greatest potential for exposure to contaminants via the air pathway, given that breathing is essential and that a rather large exchange boundary exists due to the large volume of air respired and the large surface area within the lung. However, several natural mechanisms are present within the respiratory tract that aid in trapping and removing foreign material inhaled with air. The nasopharyngeal cavity can remove up to 50 percent or more of inhaled toxicants (Klassen, 1986). Larger particles are generally deposited in this area of the respiratory tract by impaction and are removed by physiological scrubbing mechanisms. It should be noted that intake estimated under the various exposure scenarios via inhalation do not consider these removal mechanisms; thus, 100 percent of contaminants in inhaled air is assumed to reach the lower respiratory tract, a conservative assumption. Also, dust concentrations are based on total suspended particulates (TSP). Use of TSP concentrations will result in overestimates of intake through inhalation because the TSP concentration includes particles of nonrespirable sizes.

6.4 Uncertainties in the Risk Characterization

Risks are estimated for the three receptor groups, construction worker, nearby resident, and recreational receptor, assuming upper bound exposure conditions. For certain conditions, maximum exposure concentration parameters were used for screening assessment. Upper bound risk estimates calculated with maximum screening parameters will likely overestimate actual risks. When maximum screening calculations resulted in risks greater than 1×10^{-6}, the pathway was reevaluated using average and 95 percent UCL exposure parameters. The 95 percent UCL exposure parameters were used to determine "upper bound" risks. The upper bound risk estimate assumes that the constituents of concern are evenly distributed throughout the site in which contact is possible at concentrations that are equal to the 95 percent UCL on the mean concentrations. The average risk estimates assume that concentrations are evenly distributed at concentrations equal to the mean constituent concentrations. Because a large degree of variability in exposure parameters may exist for receptors, most likely the exposure parameters will be lower than those assumed for this risk assessment, and the resulting risks may correspondingly lower than those presented.

For the construction "hot spot" scenario, maximum contaminant concentrations were multiplied by a factor of 10.0 to determine upper bound risks. This results in a very conservative estimate of risk and increases the uncertainty in the high risk number by approximately 10.0.

For radiological risks, secular equilibrium between parent and daughter radionuclides is assumed. This assumption results in conservative estimates of risk since short-lived daughter (or decay) products are included in the risk calculations at concentrations equal to the parent radionuclides. Their daughter products may not be present under actual exposure conditions.

Section 7

Summary and Conclusions

This risk assessment presents risks of exposure to chemical and radiological contaminants in soil and sediments during construction of the SLDP. Risks are summarized for construction worker, construction "hot spot," residential, and future recreational exposure scenarios via incidental ingestion of soils, inhalation of contaminants in suspended dust, and direct gamma exposure. In addition, qualitative evaluations are shown for future exposures to contaminants suspended and redeposited during construction activities, and radiological risks for exposures to children. A summary of risks associated with exposure to contaminants during construction of the SLDP under each scenario is shown in Table 7-1.

Under the construction scenario, total chemical carcinogenic risks are 3×10^{-7} for upper bound exposure conditions, primarily as a result of inhalation of nickel, and 2×10^{-7} for the average exposure conditions, again through inhalation of nickel. The HI for noncarcinogens ranges from an average of 0.28 to an upper bound of 0.53 for construction workers. Risks associated with chemical carcinogens and noncarcinogens is due primarily to ingestion of manganese.

Total radiological risks under the construction scenario range from 2×10^{-6} for average exposure conditions, to 3×10^{-6} for upper bound exposure conditions. Radiological risks are driven by inhalation of U-234 and U-238. The concentrations of U-234 and U-238 used in this analysis are representative of background concentrations of uranium in the Rocky Mountain area. While these concentrations result in inhalation risks that fall within the target risk range of 10^{-6} to 10^{-4}, these risks are not considered related to past releases from the RFP.

Table 7-1
Summary of Risks Associated with Exposure to Contaminants During Construction of the SLDP

Scenario	Total Chemical Risks				Total Radiological Risks	
	Average Exposure		Upper Bound Exposure			
	Excess Cancer Risk	Hazard Index	Excess Cancer Risk	Hazard Index	Average Exposure	Upper Bound Exposure
Construction Worker	2×10^{-7}	0.28	3×10^{-7}	0.53	2×10^{-6}	3×10^{-6}
Construction "Hot Spot"	NA	NA	NA	0.01	NA	2×10^{-8}
Residential	1×10^{-7}	0.14	2×10^{-7}	0.26	1×10^{-6} (2×10^{-6}a)	2×10^{-6} ($3 \times 10^{-6a)}$
Recreational	NA	NA	NA	0.005	NA	3×10^{-7}

[a]Upper bound qualitative risk estimate for child exposure to radioactive contaminants.
Note:

NA = Not Applicable

The construction "hot spot" scenario was evaluated for ingestion of soils due to concerns that localized areas of elevated contamination could contribute to risks to construction workers. A screening analyses was performed to evaluate this scenario under upper bound conditions, which result in a HI of 0.01, well below 1.0. Similarly, upper bound radiological risks are approximately 2×10^{-8}.

Total chemical carcinogenic risks estimated for nearby residents range from 1×10^{-7} for average exposure conditions to 2×10^{-7} for upper bound exposure conditions. Noncarcinogenic hazard indices for this receptor group range from 0.14 for average exposure conditions to 0.26 for upper bound exposure conditions. These results are well below the risk range of concern. As with the construction scenario, chemical risks are associated primarily with ingestion of manganese.

Total radiological risks under the residential scenario range from 1×10^{-6} for average exposure conditions, to 2×10^{-6} for upper bound exposure conditions. As with the construction scenario, radiological risks are primarily associated with inhalation of background concentrations of naturally occurring uranium.

A future recreational scenario was evaluated to determine if longer-term exposures to contaminants in the canal area could pose significant risks. A screening analysis was conducted of this scenario, using upper bound conditions. The HI associated with the recreational upper bound exposures is 0.005. Upper bound radiological risks due to recreational exposures are 3×10^{-7}.

In general, risks associated with exposure to contaminants in soil and sediments during construction of the SLDP are minimal. The EPA uses a risk range of 10^{-4} to 10^{-6} for the purpose of making remedial action decisions on Superfund sites. The maximum incremental risk of cancer incidence calculated in this assessment is 3×10^{-6} (construction worker scenario, and child radiological evaluation). This risk is at the low end of the range that EPA uses for decision making, and represents an increased chance of cancer incidence of 3 cancers in a population of 1 million persons. This risk is also

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small in comparison the current U.S. average lifetime risk of developing cancer (approximately 0.2, or 1 cancer per 5 individuals).

Appendix A

Modeled Dust Concentrations for Construction and Residential Receptors

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FUGITIVE DUST CONCENTRATIONS FROM TOPSOIL & SUBSURFACE SOIL
CONSTRUCTION RECEPTORS

RECEPTOR LOCATION X(ft)	Y(ft)	RECP ID#	Top dust (ug/m^3)	Sub dust (ug/m^3)	Total (ug/m^3)
26180	51180	16	228.0	2346.2	2574.2
26560	51650	17	266.1	2746.1	3012.2
26820	50780	18	247.2	2523.1	2770.3
27230	50260	19	239.7	2458.4	2698.1
27920	50990	21	232.6	2558.4	2791.0
27960	50280	22	219.4	2311.9	2531.3
27990	51350	23	222.3	2765.0	2987.3
28320	51490	24	122.9	4582.8	4705.7
28620	51420	25	93.5	4606.7	4700.2
28900	51350	26	88.9	4891.5	4980.3
29180	51360	27	75.7	4353.0	4428.7
29460	51420	28	72.1	4279.3	4351.4
29590	51680	29	98.0	6050.8	6148.8
29800	51930	30	82.8	5108.1	5190.9
30100	51940	31	77.1	4793.1	4870.2
30400	51950	32	77.9	4884.5	4962.4
30710	51960	33	73.3	4601.9	4675.2
31000	51970	36	66.5	4169.3	4235.8
31220	52140	37	104.5	6690.0	6794.5
31540	52300	39	70.3	4434.9	4505.2
31850	52310	41	79.7	5049.9	5129.6
32150	52300	43	72.0	4514.8	4586.8
32460	52300	45	74.2	4607.4	4681.6
32760	52300	47	69.3	4094.3	4163.6
33100	52280	49	72.4	3681.9	3754.3
33410	52280	50	72.5	3626.2	3698.6
33710	52280	52	72.4	3599.5	3671.9
34010	52280	54	72.9	3609.0	3681.9
34310	52280	56	69.4	3419.6	3489.0
34610	52280	58	74.1	3642.6	3716.7
34900	52280	60	73.9	3622.9	3696.8
35210	52290	62	71.2	3467.4	3538.7
35510	52290	63	46.6	2189.7	2236.4
35810	52290	65	19.8	794.6	814.5
36110	52290	67	23.6	958.8	982.4
36410	52290	69	60.3	2798.1	2858.5
36710	52300	71	85.5	4033.2	4118.7
37010	52300	72	92.6	4322.7	4415.3
37310	52300	74	101.1	4683.9	4784.9
37600	52230	76	95.9	4274.6	4370.5
37870	52080	78	104.2	4456.0	4560.2

38080	51840	79	126.3	5213.1	5339.4
38210	51610	80	95.7	3155.2	3250.9
38370	51320	81	69.5	1576.9	1646.3
38740	51520	83	299.8	5861.0	6160.8
39030	51580	85	268.1	5206.4	5474.5
39340	51620	87	317.1	6114.6	6431.7
39660	51560	88	288.2	5545.4	5833.6
39940	51460	90	280.5	5390.0	5670.5
40220	51300	92	192.4	3703.4	3895.8
40450	51100	93	113.7	2199.1	2312.9
40630	50860	94	201.0	3858.9	4059.9
40790	50600	99	332.5	6362.2	6694.7
40960	50340	100	285.1	5456.0	5741.1
41110	50100	101	289.8	5543.8	5833.6
41280	49850	102	167.1	3204.1	3371.2
41440	49590	105	244.2	4672.4	4916.6
41600	49340	106	293.1	5603.8	5897.0
41870	49240	107	291.1	5564.1	5855.2
42100	49540	108	288.5	5512.4	5800.8
41760	48990	109	142.9	2738.7	2881.5
42160	49340	110	287.1	5485.1	5772.2
42170	49060	111	199.1	3809.1	4008.2
42440	49300	112	243.1	4645.6	4888.7
42580	49380	113	242.2	4629.0	4871.2

Construction Dust Concentration Statistics

average dust concs:	151.1	4117.7
Std. dev. of dust concs:	91.5	1284.9
95 th UCL of dust concs:	170.0	4383.9

FUGITIVE DUST CONCENTRATIONS FROM TOPSOIL & SUBSURFACE SOIL
RESIDENTIAL RECEPTORS

RECEPTOR LOCATION X(ft)	Y(ft)	RECP ID#	Top dust (ug/m^3)	Sub dust (ug/m^3)	Total (ug/m^3)
26024	49907	1	24.4	296.2	320.6
30002	51578	2	29.4	1611.3	1640.8
30319	51347	3	18.9	954.2	973.1
30529	50683	4	11.7	473.9	485.5
30623	50884	5	12.6	545.3	557.9
30743	51244	6	15.8	775.5	791.3
30743	52324	7	52.0	3199.1	3251.1
35647	51702	8	19.5	803.2	822.8
36048	52119	9	45.8	2102.3	2148.2
36030	52238	10	74.5	3567.7	3642.1
36369	52647	11	54.8	2528.3	2583.2
38142	52540	12	49.2	1633.4	1682.6
41549	51242	13	53.3	1037.6	1090.9
42766	48966	14	55.0	1060.1	1115.1
42779	50112	15	51.3	992.2	1043.5
27600	49460	20	37.1	450.2	487.3
30580	52600	34	34.9	2040.6	2075.4
30940	52590	35	37.9	2273.6	2311.5
31310	52580	38	50.1	3090.8	3140.9
31670	52580	40	57.8	3600.3	3658.0
32020	52580	42	58.1	3607.1	3665.2
32380	52580	44	58.2	3560.9	3619.1
32750	52580	46	59.0	3448.8	3507.8
33110	52570	48	60.9	3094.9	3155.8
33470	52570	51	60.5	3002.6	3063.0
33830	52560	53	61.4	3028.3	3089.6
34180	52560	55	60.8	2983.2	3044.0
34550	52560	57	61.0	2977.6	3038.6
34910	52550	59	63.2	3074.1	3137.3
35270	52560	61	62.6	3023.3	3085.9
35630	52560	64	63.7	3054.1	3117.8
35990	52560	66	64.6	3071.6	3136.3
36350	52560	68	65.5	3076.5	3142.0
36720	52550	70	67.5	3117.5	3185.0
37070	52550	73	67.5	3056.2	3123.7
37420	52550	75	67.3	2947.9	3015.2
37780	52550	77	57.8	2309.2	2366.9
38500	52560	82	50.9	1247.1	1298.0
38890	52550	84	67.8	1411.3	1479.1
39350	52550	86	73.3	1463.8	1537.2
39750	52550	89	78.3	1539.3	1617.6
40080	52540	91	65.8	1294.1	1359.9
40620	52540	95	51.2	1006.5	1057.7
40880	52540	96	49.0	960.7	1009.6
41740	52530	97	27.9	551.8	579.7
41750	50900	98	58.9	1141.0	1199.8
42380	50580	103	59.1	1141.8	1200.9
42540	50310	104	65.6	1264.7	1330.3

Appendix B
Intake and Risk Calculations

Residential Dust Concentration Statistics

Average of dust concs:	51.9	2051.9
Std. dev. of dust concs:	16.9	1062.0
95th UCL of dust concs:	56.0	2309.4

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Table B-1 Ingestion of Contaminated Soils Standley Lake Diversion Project Intake and risk calculations for construction worker Upper bound (approximate RME) evaluation				
Samples SB#-Comp, SL#-Comp, SD#		Maximum constituent concentrations from composite soil boring, composite surface soil, or composite sediment samples		
Chemical	Soil Conc. (mg/kg)	Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient intake/RfD
Manganese	1400.0	6.58E-03	0.1	0.065753
Nickel	30.0	1.41E-04	0.02	0.007045

Intake = CS x IR x CF x FI x EF x ED/BW x AT

exposure parameters

CS=		mg/kg	max. soil or sediment conc. (CH2M Hill, 1992 field data)
IR=	480	mg soil/day	ingestion rate (EPA, 1991a)
CF=	1.0E-06	kg/mg	soil conversion factor (EPA, 1989a)
FI=	1		fraction ingested (EPA, 1989a)
EF=	250	days/year	exposure frequency (CH2M Hill, 1993 Tech Memo)
ED=	1	year	exposure duration (CH2M Hill, 1993 Tech Memo)
BW=	70	kg	body weight (EPA, 1991a)
AT=	365	days	averaging time noncarcinogenic effects (EPA, 1989a)
AT=	25550	days	averaging time carcinogenic effects (CH2M Hill, 1989a)

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Table B-2
Modeled Airborne Metal Concentrations
From Surface Soils and Subsurface Soils
For Construction Worker Receptor
Standely Lake Diversion Project

Modeled Dust Concentrations				Modeled Dust Metal Concentrations (ug/cu.m)		
Concentrations By Topsoil		Concentrations By Subsoil		(SC1) (SC2)	Mn soil conc. (ug/g)	Ni
	(DC1) top dust (ug/cu.m)		(DC2) sub dust (ug/cu.m)	ave	346.5	13.6
				ave	330.5	16.4
				95%UCL	367.4	16.5
				95%UCL	509.5	19.5
AVE	151.1		4117.7		1.41E+00	6.96E-02
95%UCL	170.0		4383.9		2.30E+00	8.83E-02
MAX at 99	332.5	MAX AT 3	6690.0		3.53E+00	1.36E-01

ADC= (DC1 x SC1 x CF)+(DC2 x SC2 x CF)

where:
DC1= topsoil dust concentration (ug/cu.m)
DC2= subsurface dust concentration (ug/cu.m)
SC1= constituent concentration in surface soil sample SB-0.5 (ug/g)
SC2= constituent concentration in subsurface soil sample SB-Comp (ug/g)
CF= conversion factor (0.000001 g/ug)

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Table B-3
Inhalation of Contaminated Dust
Standley Lake Diversion Project
Intake and risk calculations for construction worker
Average Evaluation

Samples SB#-Comp, SL#-Comp		*Mean constituent concentration from composite soil boring samples and composite surface soil samples used in estimating total concentrations in air*				
Chemical	Ave Total Conc in Air (mg/cu.m)	Intake (mg/kg-day)	Inhalation SF (kg-day/mg)	Inhalation RfD (mg/kg-day)	ELCR intake x SF	Hazard Quotient intake/RfD
Manganese	1.41E-03	3.9E-04		0.00138		0.279929
Nickel (dust)	6.96E-05	2.7E-07	0.84		2E-07	

Intake = CA x IR x EF x ED/BW x AT

exposure parameters

CA=		mg/cu.m	modeled conc. in air (CH2M Hill, 1992 field data)
IR=	20	cu.m/day	inhalation rate (EPA, 1991a)
EF=	350	days/year	exposure frequency (CH2M Hill, 1993 Tech Memo)
ED=	1	year	exposure duration (CH2M Hill, 1993 Tech Memo)
BW=	70	kg	body weight (EPA, 1991a)
AT=	365	days	averaging time for noncarcinogenic effects (EPA, 1989a)
AT=	25550	days	averaging time for carcinogenic effects (EPA, 1989a)

Notes: Inhalation RfDs are calculated based on published reference concentrations times the total amount of air respired per kilogram body weight per day (0.29cu.m/kg-day)
An exposure frequency of 350 days/yr is used for construction workers to be consistent with the methods used for calculating annual average dust concentrations.

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Table B-4
Inhalation of Contaminated Dust
Standley Lake Diversion Project
Intake and risk calculations for construction worker
Upper bound (approximate RME) evaluation

Samples SB#-Comp, SL#-Comp		95% UCL constituent concentration from composite soil boring samples and composite surface soil samples used in estimating total concentrations in air				
Chemical	95 % UCL Conc in Air (mg/cu.m)	Intake (mg/kg-day)	Inhalation SF (kg-day/mg)	Inhalation RfD (mg/kg-day)	ELCR intake x SF	Hazard Quotient intake/RfD
Manganese	2.30E-03	6.3E-04		0.00138		0.456621
Nickel (dust)	8.83E-05	3.5E-07	0.84		3E-07	

Intake = CA x IR x EF x ED/BW x AT

exposure parameters

CA=		mg/cu.m	modeled conc. in air (CH2M Hill, 1992 field data)
IR=	20	cu.m/day	inhalation rate (EPA, 1991a)
EF=	350	days/year	exposure frequency (CH2M Hill, 1993 Tech Memo)
ED=	1	year	exposure duration (CH2M Hill, 1993 Tech Memo)
BW=	70	kg	body weight (EPA, 1991a)
AT=	365	days	averaging time for noncarcinogenic effects (EPA, 1989a)
AT=	25550	days	averaging time for carcinogenic effects (EPA, 1989a)

Note: Inhalation RfDs are calculated based on published reference concentrations times the total amount of air respired per kilogram body weight per day (0.20cu.m/kg-day). An exposure frequency of 350 days/yr is used for construction workers to be consistent with the methods used for calculating annual average dust concentrations.

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Table B-5

STANDLEY LAKE DIVERSION PROJECT

EXCESS LIFETIME RISK OF CANCER INCIDENCE

INGESTION OF SOIL OR SEDIMENT

CONSTRUCTION MAXIMUM EXPOSURE SCENARIO

RADIONUCLIDE (a)	MAXIMUM SAMPLE CONCENTRATION (SC) (pCi/g)(b)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INGESTION DOSE CONVERSION FACTOR (c) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (d)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INGESTION (RF) (pCi)-1 (e)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER INCIDENCE
U-234	1.57	188.4	188.4	2.83E-04	5.33E-02	5.33E-02	1.60E-11	3.01E-09	3.4
U-235 +D	0.192	23.04	23.04	2.66E-04	6.13E-03	6.13E-03	1.60E-11	3.69E-10	0.4
U-238 +D	1.49	178.8	178.8	2.55E-04	4.56E-02	4.56E-02	2.80E-11	5.01E-09	5.7
PU-239	0.718	86.16	86.16	3.69E-04	3.18E-02	3.18E-02	2.30E-10	1.98E-08	22.5
AM-241	2.08	249.6	249.6	3.64E-03	9.09E-01	9.09E-01	2.40E-10	5.99E-08	68.0
TOTAL					1.05E+00	1.05E+00		8.8E-08	

EXPOSURE ASSUMPTIONS

Exposure scenario: Worker ingestion of contaminated soil

Risk = SC x IR x EF x ED x RF

Worker ingestion rate (IR) (g/day):	0.48
Exposure frequency (EF) (days/year):	250
Exposure duration (ED) (years):	1

NOTES:

(a) Radionuclides shown with +D include daughter products in risk calculations.

(b) Concentrations shown are the maximum surface soil, soil boring, or sediment sample concentration detected for each radionuclide.

(c) Dose factors taken from Federal Guidance Report 11, "Limiting Values Of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion" (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.

(d) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).

(e) Cancer risk factors taken from January 1992 HEAST tables.

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TABLE B-6
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
INHALATION OF CONTAMINATED SOIL
AVERAGE WORKER EXPOSURE SCENARIO
AVERAGE SOIL CONCENTRATIONS, AVERAGE DUST CONCENTRATIONS

RADIONUCLIDE (a)	SURFACE SOIL SAMPLE CONCENTRATION (SC1) (pCi/g)	SUBSURFACE SOIL SAMPLE CONCENTRATION (SC2) (pCi/g)	AIRBORNE RADIOACTIVITY CONCENTRATION (ARC) (pCi/m3)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INHALATION DOSE CONVERSION FACTOR (b) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (c)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INHALATION (RF) (pCi)-1 (d)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER INCIDENCE
U-234	1.092	1.045	4.47E-03	31.3	31.3	1.33E-01	4.16E+00	4.16E+00	2.60E-08	8.14E-07	33.6
U-235 +D	0.062	0.053	2.28E-04	1.6	1.6	1.23E-01	1.96E-01	1.96E-01	2.50E-08	3.99E-08	1.6
U-238 +D	1.062	0.978	4.19E-03	29.3	29.3	1.18E-01	3.46E+00	3.46E+00	5.20E-08	1.53E-06	62.9
PU-239	0.173	0.01	6.73E-05	0.5	0.5	3.08E-01	1.45E-01	1.45E-01	3.80E-08	1.79E-08	0.7
AM-241	0.434	0.0138	1.22E-04	0.9	0.9	4.43E-01	3.80E-01	3.80E-01	3.20E-08	2.74E-08	1.1
TOTAL							8.3E+00	8.3E+00		2.4E-06	

EXPOSURE ASSUMPTIONS

Exposure scenario: Worker inhalation of contaminated soil

Dust concentration from surface soil (DC1) (mg/m3):	0.151	ARC = (SC1 x DC1 x CF) + (SC2 x DC1 x CF)
Dust Concentration from subsurface soil (DC2) (mg/m3):	4.12	Risk = ARC x IR x EF x ED
Worker inhalation rate (IR) (m3/day):	20	
Exposure frequency (EF) (days/year):	350	
Exposure duration (ED) (years):	1	
Conversion factor (CF) (1 g/1000 mg):	0.001	

NOTES:

(a) Radionuclides shown with +D include decay products in risk calculations

(b) Dose factors taken from Federal Guidance Report 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.

(c) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).

(d) Cancer risk factors taken from January 1992 HEAST tables.

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WKINHAVE.WK1

TABLE B-7
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
INHALATION OF CONTAMINATED SOIL
UPPER BOUND WORKER EXPOSURE SCENARIO
95 % UCL SOIL CONCENTRATIONS, 95 % UCL DUST CONCENTRATIONS

RADIONUCLIDE (a)	SURFACE SOIL SAMPLE CONCENTRATION (SC1) (pCi/g)	SUBSURFACE SOIL SAMPLE CONCENTRATION (SC2) (pCi/g)	AIRBORNE RADIOACTIVITY CONCENTRATION (ARC) (pCi/m3)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INHALATION DOSE CONVERSION FACTOR (b) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (c)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INHALATION (RF) (pCi)-1 (d)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER INCIDENCE
U-234	1.339	1.342	6.11E-03	42.7	42.7	1.33E-01	5.68E+00	5.68E+00	2.60E-08	1.11E-06	33.2
U-235 +D	0.121	0.086	3.97E-04	2.8	2.8	1.23E-01	3.42E-01	3.42E-01	2.50E-08	6.95E-08	2.1
U-238 +D	1.242	1.246	5.67E-03	39.7	39.7	1.18E-01	4.68E+00	4.68E+00	5.20E-08	2.06E-06	61.6
PU-239	0.292	0.0226	1.49E-04	1.0	1.0	3.08E-01	3.20E-01	3.20E-01	3.80E-08	3.95E-08	1.2
AM-241	1.099	0.0219	2.83E-04	2.0	2.0	4.43E-01	8.77E-01	8.77E-01	3.20E-08	6.33E-08	1.9
TOTAL							1.2E+01	1.2E+01		3.3E-06	

EXPOSURE ASSUMPTIONS

Exposure scenario: Worker inhalation of contaminated soil	
Dust concentration from surface soil (DC1) (mg/m3):	0.17
Dust Concentration from subsurface soil (DC2) (mg/m3):	4.38
Worker inhalation rate (IR) (m3/day):	20
Exposure frequency (EF) (days/year):	350
Exposure duration (ED) (years):	1
Conversion factor (CF) (1 g/1000 mg):	0.001

ARC = (SC1 x DC1 x CF) + (SC2 x DC2 x CF)
Risk = ARC x IR x EF x ED

NOTES:
(a) Radionuclides shown with +D include decay products in risk calculations
(b) Dose factors taken from Federal Guidance Report 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.
(c) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).
(d) Cancer risk factors taken from January 1992 HEAST tables.

Table B-8
STANDLEY LAKE DIVERSION CANAL PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
EXPOSURE TO EXTERNAL RADIATION FROM CONTAMINATED SOIL OR SEDIMENT
WORKER MAXIMUM EXPOSURE SCENARIO

RADIONUCLIDE (a)	MAXIMUM SOIL CONCENTRATION (SC) (pCi/g)(b)	SURFACE DOSE CONVERSION FACTOR (c) (mrem-g/pCi-hr)	ANNUAL EFFECTIVE DOSE EQUIVALENT (mrem/yr)	TOTAL EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR EXT. EXPOSURE (d) (RF) (risk-g/pCi-y)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER RISK
U-234	1.57	5.70E-08	2.24E-04	2.24E-04	3.00E-11	1.40E-11	0.0
U-235 +D	0.192	3.80E-05	1.82E-02	1.82E-02	2.40E-07	1.37E-08	41.9
U-238 +D	1.49	7.50E-06	2.79E-02	2.79E-02	3.60E-08	1.60E-08	48.8
Pu-239	0.718	4.20E-08	7.54E-05	7.54E-05	1.70E-11	3.63E-12	0.0
Am-241	2.08	4.30E-06	2.24E-02	2.24E-02	4.90E-09	3.03E-09	9.3
TOTALS			6.88E-02	6.88E-02		3.27E-08	

EXPOSURE ASSUMPTIONS

Exposure scenario: Worker exposure to external radiation from contaminated soil or sediment

Exposure Time (ET) (hr/day)	10	
Exposure Frequency (EF) (days/year):	250	Risk = SC x ED x Te x (1 - SF) x RF
Exposure duration (ED) (years):	1	
Shielding factor (SF):	0	
Fraction of year exposed (Te):	0.30	

NOTES:
(a) Radionuclides shown with +D include daughter products in the risk calculations.
(b) Concentrations shown are the maximum surface soil, soil boring, or sediment sample concentration detected for each radionuclide.
(c) Dose factors from NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Dose".
(d) Cancer incidence risk factors taken from January, 1992 Health Effects Summary Tables (HEAST).

Table B-9
Ingestion of Contaminated Soils
Standley Lake Diversion Project
Intake and risk calculations for construction worker
Hot spot evaluation

Samples SB#-0.5		maximum concentrations from shallow soil boring discrete samples		
Chemical	Soil Conc. (mg/kg)	Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient intake/RfD
Manganese	4430	8.32E-04	0.1	0.008323
Nickel	304	5.71E-05	0.02	0.002856

Intake = CS x IR x CF x FI x EF x ED/BW x AT

exposure parameters

CS=		mg/kg	max. soil conc. (CH2M Hill, 1992 field data)
IR=	480	mg soil/day	ingestion rate (EPA, 1991a)
CF=	1.0E-06	kg/mg	soil conversion factor (EPA, 1989a)
FI=	1		fraction ingested (EPA, 1989a)
EF=	10	days/year	exposure frequency (CH2M Hill, 1993 Tech Memo)
ED=	1	year	exposure frequency (CH2M Hill, 1993 Tech Memo)
BW=	70	kg	body weight (EPA, 1991a)
AT=	365	days	averaging time noncarcinogenic effects (EPA, 1989a)
AT=	25550	days	averaging time carcinogenic effects (EPA, 1989a)

CWHSSBO5.WK1

TABLE B-10
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
INGESTION OF SOIL
WORKER "HOT SPOT" EXPOSURE SCENARIO

RADIONUCLIDE (a)	ADJUSTED SOIL CONCENTRATION (SC) (pCi/g)(b)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INGESTION DOSE CONVERSION FACTOR (c) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (d)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INGESTION (RF) (pCi)-1 (e)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER INCIDENCE
U-234	11.9	57.12	57.12	2.83E-04	1.62E-02	1.62E-02	1.60E-11	9.14E-10	8.0
U-235 +D	0.81	3.888	3.888	2.66E-04	1.03E-03	1.03E-03	1.60E-11	6.22E-11	0.5
U-238 +D	12.5	60	60	2.55E-04	1.53E-02	1.53E-02	2.80E-11	1.68E-09	14.8
PU-239	6.5	31.2	31.2	3.69E-04	1.15E-02	1.15E-02	2.30E-10	7.18E-09	63.1
AM-241	1.33	6.384	6.384	3.64E-03	2.32E-02	2.32E-02	2.40E-10	1.53E-09	13.5
TOTAL					6.72E-02	6.72E-02		1.1E-08	

EXPOSURE ASSUMPTIONS

Exposure scenario: Worker ingestion of contaminated soil

Risk = SC x IR x EF x ED x RF

Worker ingestion rate (IR) (g/day):	0.48
Exposure frequency (EF) (days/year):	10
Exposure duration (ED) (years):	1

NOTES:
(a) Radionuclides shown with +D include daughter products in risk calculations.
(b) "Adjusted" concentrations used for the hot spot analysis are the maximum discreet top interval soil boring (SB-0.5) sample concentration multiplied by 10.0
(c) Dose factors taken from Federal Guidance Report 11, "Limiting Values Of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion" (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.
(d) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).
(e) Cancer risk factors taken from January 1992 HEAST tables.

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WKHOTING.WK1

TABLE B-11
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
EXPOSURE TO EXTERNAL RADIATION FROM CONTAMINATED SURFACE SOILS
WORKER "HOT SPOT" EXPOSURE SCENARIO

RADIONUCLIDE (a)	ADJUSTED SOIL CONCENTRATION (SF) (pCi/g)(b)	SURFACE DOSE CONVERSION FACTOR (c) (mrem-g/pCi-hr)	ANNUAL EFFECTIVE DOSE EQUIVALENT (mrem/yr)	TOTAL EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR EXT. EXPOSURE (d) (RF) (risk-g/pCi-y)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER RISK
U-234	11.9	5.70E-08	6.78E-05	6.78E-05	3.00E-11	4.25E-12	0.1
U-235 +D	0.81	3.80E-05	3.08E-03	3.08E-03	2.40E-07	2.31E-09	29.8
U-238 +D	12.5	7.50E-06	9.37E-03	9.37E-03	3.60E-08	5.36E-09	69.1
Pu-239	6.5	4.20E-08	2.73E-05	2.73E-05	1.70E-11	1.32E-12	0.0
Am-241	1.33	4.30E-06	5.72E-04	5.72E-04	4.90E-09	7.76E-11	1.0
TOTALS			1.31E-02	1.31E-02		7.75E-09	

EXPOSURE ASSUMPTIONS

Exposure scenario: Worker exposure to external radiation from discreet locations of contamination (hot spots).

Exposure Time (ET) (hr/day): 10
Exposure Frequency (EF) (days/year): 10
Exposure duration (ED) (years): 1
Shielding factor (SF): 0
Fraction of year exposed (Te): 0.01

Risk = SC x ED x Te x (1 - SF) x RF

NOTES:
(a) Radionuclides shown with +D include daughter products in the risk calculations.
(b) "Adjusted" concentrations used for the hot spot analysis are the maximum discreet top interval soil boring (SB-0.5) sample multiplied by 10.0.
(c) Dose factors from NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Dose".
(d) Cancer incidence risk factors taken from January, 1992 Health Effects Summary Tables (HEAST).

Table B-12
Ingestion of Contaminated Soils or Sediments
Standley Lake Diversion Project
Intake and risk calculations for adult resident receptor
Upper Bound (approximate RME) evaluation

Samples SL#-Comp, SB#-Comp, SD#	Maximum constituent concentration from composite surface soil, composite soil boring, or composite sediment samples			
Chemical	Soil Conc. (mg/kg)	Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient intake/RfD
Manganese	1400.0	1.92E-03	0.1	0.019178
Nickel	30.0	4.11E-05	0.02	0.002055

Intake = CS x IR x CF x FI x EF x ED/BW x AT

exposure parameters			
CS=		mg/kg	maximum soil conc. (CH2M Hill, 1992 field data)
IR=	100	mg soil/day	ingestion rate (EPA, 1991a)
CF=	1.0E-06	kg/mg	soil conversion factor (EPA, 1989a)
FI=	1		fraction ingested (EPA, 1989a)
EF=	350	days/year	exposure frequency (CH2M Hill, 1993 Tech Memo)
ED=	1	year	exposure frequency (CH2M Hill, 1993 Tech Memo)
BW=	70	kg	body weight (EPA, 1991a)
AT=	365	days	averaging time noncarcinogenic effects (EPA, 1989a)
AT=	25550	days	averaging time carcinogenic effects (EPA, 1989a)

ADUBING.WK1

Table B-13
Modeled Dust Metal Concentrations
In Surface Soils and Subsurface Soils
For Resident Receptor
Standley Lake Diversion Project

Modeled Dust Concentrations				Modeled Dust Metal Concentrations (ug/cu.m)		
Concentrations By Topsoil		Concentrations By Subsoil		(SC1) (SC2)	Mn soil conc (ug/g)	Ni
				ave	346.5	13.6
	(DC1)		(DC2)	ave	330.5	16.4
	top dust		sub dust	95%UCL	367.4	16.5
	(ug/cu.m)		(ug/cu.m)	95%UCL	509.5	19.5
AVE	51.9		2051.9		6.96E-01	3.44E-02
95%UCL	56.0		2309.4		1.20E+00	4.60E-02
MAX at 89	78.3	42	3607.1		1.87E+00	7.16E-02

ADC= (DC1 x SC1 x CF)+(DC2 x SC2 x CF)

where: DC1= topsoil dust concentration (ug/cu.m)
DC2= subsurface dust concentration (ug/cu.m)
SC1= maximum constituent concentration in surface soil sample SB-0.5 (ug/g)
SC2= constituent concentration in subsurface soil sample SB-Comp (ug/g)
CF= conversion factor (0.000001 g/ug)

RESDUST.WK1

Table B-14
Inhalation of Contaminated Dust
Standley Lake Diversion Project
Intake and risk calculations for adult resident receptor
Average Evaluation

Samples SB#-Comp, SL#-Comp	Mean constituent concentrations from composite soil boring samples and composite surface soil samples used in estimating total constituent concentrations in air					
Chemical	Ave Total Conc in Air (mg/cu.m)	Intake (mg/kg-day)	Inhalation SF (kg-day/mg)	Inhalation RfD (mg/kg-day)	ELCR intake x SF	Hazard Quotient intake/RfD
Manganese	6.96E-04	1.9E-04		0.00138		0.138177
Nickel(dust)	3.44E-05	1.3E-07	0.84		1E-07	

Intake = CA x IR x EF x ED/BW x AT

exposure parameters

CA=		mg/cu.m	modeled conc. in air (CH2M Hill, 1992 field data)
IR=	20	cu.m/day	inhalation rate (EPA, 1991a)
EF=	350	days/year	exposure frequency (CH2M Hill, 1993 Tech Memo)
ED=	1	year	exposure duration (CH2M Hill, 1993 Tech Memo)
BW=	70	kg	body weight (EPA, 1991a)
AT=	365	days	averaging time for noncarcinogenic effects (EPA, 1989
AT=	25550	days	averaging time for carcinogenic effects (EPA, 1989a)

note: inhalation RfDs are calculated based on published reference concentrations times the total amount of air respired per kilogram body weight per day (0.29cu.m/kg-day)

AVEINRES.WK1

Table B-15
Inhalation of Contaminated Dust
Standley Lake Diversion Project
Intake and risk calculations for adult resident receptor
Upper Bound (approximate RME) Evaluation

Samples SB#-Comp, SL#-Comp		95% UCL constituent concentrations from composite soil boring samples and composite surface soil samples used in estimating total constituent concentrations in air				
Chemical	Max Total Conc in Air (mg/cu.m)	Intake (mg/kg-day)	Inhalation SF (kg-day/mg)	Inhalation RfD (mg/kg-day)	ELCR intake x SF	Hazard Quotient intake/RfD
Manganese	1.20E-03	3.3E-04		0.00138		0.238237
Nickel (dust)	4.60E-05	1.8E-07	0.84		2E-07	

Intake = CA x IR x EF x ED/BW x AT

exposure parameters

CA=		mg/cu.m	modeled conc. in air (CH2M Hill, 1992 field data)
IR=	20	cu.m/day	inhalation rate (EPA, 1991a)
EF=	350	days/year	exposure frequency (CH2M Hill, 1993 Tech Memo)
ED=	1	year	exposure duration (CH2M Hill, 1993 Tech Memo)
BW=	70	kg	body weight (EPA, 1991a)
AT=	365	days	averaging time for noncarcinogenic effects (EPA, 1989a)
AT=	25550	days	averaging time for carcinogenic effects (EPA, 1989a)

note: inhalation RfDs are calculated based on published reference concentrations times the total amount of air respired per kilogram body weight per day (0.29cu.m/kg-day)

UBINHRES.WK1

TABLE B-16
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
INGESTION OF SOIL OR SEDIMENT
RESIDENTIAL MAXIMUM EXPOSURE SCENARIO

RADIONUCLIDE (a)	SAMPLE CONCENTRATION (SC) (pCi/g)(b)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INGESTION DOSE CONVERSION FACTOR (c) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (d)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INGESTION (RF) (pCi)-1 (e)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER INCIDENCE
U-234	1.57	54.95	54.95	2.83E-04	1.56E-02	1.56E-02	1.60E-11	8.79E-10	3.4
U-235 +D	0.192	6.72	6.72	2.66E-04	1.79E-03	1.79E-03	1.60E-11	1.08E-10	0.4
U-238 +D	1.49	52.15	52.15	2.55E-04	1.33E-02	1.33E-02	2.80E-11	1.46E-09	5.7
PU-239	0.718	25.13	25.13	3.69E-04	9.27E-03	9.27E-03	2.30E-10	5.78E-09	22.5
AM-241	2.08	72.8	72.8	3.64E-03	2.65E-01	2.65E-01	2.40E-10	1.75E-08	68.0
TOTAL					3.05E-01	3.05E-01		2.6E-08	

EXPOSURE ASSUMPTIONS

Exposure scenario: Residential ingestion of contaminated soil

Ingestion rate (IR) (g/day):	0.1	Risk = SC x IR x EF x ED x RF
Exposure frequency (EF) (days/year):	350	
Exposure duration (ED) (years):	1	

NOTES:
(a) Radionuclides shown with +D include daughter products in risk calculations.
(b) Concentrations shown are the maximum surface soil, soil boring, or sediment sample concentration detected for each radionuclide.
(c) Dose factors taken from Federal Guidance Report 11, "Limiting Values Of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion" (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.
(d) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).
(e) Cancer risk factors taken from January 1992 HEAST tables.

TABLE B-17
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
INHALATION OF CONTAMINATED SOIL
AVERAGE RESIDENTIAL EXPOSURE SCENARIO
AVERAGE SOIL CONCENTRATIONS, AVERAGE DUST CONCENTRATIONS

RADIONUCLIDE (a)	SURFACE SOIL SAMPLE CONCENTRATION (SC1) (pCi/g)	SUBSURFACE SOIL SAMPLE CONCENTRATION (SC2) (pCi/g)	AIRBORNE RADIOACTIVITY CONCENTRATION (ARC) (pCi/m3)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INHALATION DOSE CONVERSION FACTOR (b) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (c)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INHALATION (RF) (pCi)-1 (d)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER INCIDENCE
U-234	1.092	1.045	2.20E-03	15.4	15.4	1.33E-01	2.05E+00	2.05E+00	2.60E-08	4.00E-07	33.7
U-235 +D	0.062	0.053	1.12E-04	0.8	0.8	1.23E-01	9.63E-02	9.63E-02	2.50E-08	1.96E-08	1.6
U-238 +D	1.062	0.978	2.06E-03	14.4	14.4	1.18E-01	1.70E+00	1.70E+00	5.20E-08	7.50E-07	63.1
PU-239	0.173	0.01	2.95E-05	0.2	0.2	3.08E-01	6.36E-02	6.36E-02	3.80E-08	7.85E-09	0.7
AM-241	0.434	0.0138	5.09E-05	0.4	0.4	4.43E-01	1.58E-01	1.58E-01	3.20E-08	1.14E-08	1.0
TOTAL							4.1E+00	4.1E+00		1.2E-06	

EXPOSURE ASSUMPTIONS

Exposure scenario: Residential inhalation of contaminated soil	
Dust concentration from surface soil (DC1) (mg/m3):	0.052
Dust Concentration from subsurface soil (DC2) (mg/m3):	2.05
Inhalation rate (IR) (m3/day):	20
Exposure frequency (EF) (days/year):	350
Exposure duration (ED) (years):	1
Conversion factor (CF) (1 g/1000 mg):	0.001

ARC = (SC1 x DC1 x CF) + (SC2 x DC2 x CF)
Risk = ARC x IR x EF x ED

NOTES:
(a) Radionuclides shown with +D include decay products in risk calculations
(b) Dose factors taken from Federal Guidance Report 11, "Limiting Values of Radionuclide Intake and Air Concnetration and Dose Factors for Inhalation, Submersion, and Ingestion (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.
(c) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).
(d) Cancer risk factors taken from January 1992 HEAST tables.

REINHAVE.WK1

TABLE B-18
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
INHALATION OF CONTAMINATED SOIL
UPPER BOUND RESIDENTIAL EXPOSURE SCENARIO
95 % UCL SOIL CONCENTRATIONS, 95 % UCL DUST CONCENTRATIONS

RADIONUCLIDE (a)	SURFACE SOIL SAMPLE CONCENTRATION (SC1) (pCi/g)	SUBSURFACE SOIL SAMPLE CONCENTRATION (SC2) (pCi/g)	AIRBORNE RADIOACTIVITY CONCENTRATION (ARC) (pCi/m3)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INHALATION DOSE CONVERSION FACTOR (b) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (c)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INHALATION (RF) (pCi)-1 (d)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER INCIDENCE
U-234	1.339	1.342	3.18E-03	22.2	22.2	1.33E-01	2.96E+00	2.96E+00	2.60E-08	5.78E-07	33.4
U-235 +D	0.121	0.086	2.05E-04	1.4	1.4	1.23E-01	1.77E-01	1.77E-01	2.50E-08	3.60E-08	2.1
U-238 +D	1.242	1.246	2.95E-03	20.6	20.6	1.18E-01	2.43E+00	2.43E+00	5.20E-08	1.07E-06	62.0
PU-239	0.292	0.0226	6.86E-05	0.5	0.5	3.08E-01	1.48E-01	1.48E-01	3.80E-08	1.82E-08	1.1
AM-241	1.099	0.0219	1.12E-04	0.8	0.8	4.43E-01	3.48E-01	3.48E-01	3.20E-08	2.51E-08	1.5
TOTAL							6.1E+00	6.1E+00		1.7E-06	

EXPOSURE ASSUMPTIONS

Exposure scenario: Resident inhalation of contaminated soil	
Dust concentration from surface soil (DC1) (mg/m3):	0.056
Dust Concentration from subsurface soil (DC2) (mg/m3):	2.31
Worker inhalation rate (IR) (m3/day):	20
Exposure frequency (EF) (days/year):	350
Exposure duration (ED) (years):	1
Conversion factor (CF) (1 g/1000 mg):	0.001

ARC = (SC1 x DC1 x CF) + (SC2 x DC2 x CF)
Risk = ARC x IR x EF x ED

NOTES:
(a) Radionuclides shown with +D include decay products in risk calculations
(b) Dose factors taken from Federal Guidance Report 11, "Limiting Values of Radionuclide Intake and Air Concnetration and Dose Factors for Inhalation, Submersion, and Ingestion (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.
(c) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).
(d) Cancer risk factors taken from January 1992 HEAST tables.

TABLE B-19
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
EXPOSURE TO EXTERNAL RADIATION FROM CONTAMINATED SOIL OR SEDIMENT
RESIDENTIAL MAXIMUM EXPOSURE SCENARIO

RADIONUCLIDE (a)	SOIL CONCENTRATION (SC) (pCi/g)(b)	SURFACE DOSE CONVERSION FACTOR (c) (mrem-g/pCi-hr)	ANNUAL EFFECTIVE DOSE EQUIVALENT (mrem/yr)	TOTAL EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR EXT. EXPOSURE (d) (RF) (risk-g/pCi-y)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER RISK
U-234	1.57	5.70E-08	7.52E-04	7.52E-04	3.00E-11	3.77E-11	0.0
U-235 +D	0.192	3.80E-05	6.13E-02	6.13E-02	2.40E-07	3.69E-08	41.9
U-238 +D	1.49	7.50E-06	9.39E-02	9.39E-02	3.60E-08	4.29E-08	48.8
Pu-239	0.718	4.20E-08	2.53E-04	2.53E-04	1.70E-11	9.76E-12	0.0
Am-241	2.08	4.30E-06	7.51E-02	7.51E-02	4.90E-09	8.15E-09	9.3
TOTALS			2.31E-01	2.31E-01		8.80E-08	

EXPOSURE ASSUMPTIONS

Exposure scenario: Resident exposure to external gamma radiation from contaminated soil or sediment

Exposure Time (hr/day)	24
Exposure Frequency (days/year):	350
Exposure duration (years):	1
Shielding factor:	0.2
Fraction of year exposed:	1

Risk = SC x ED x Te x (1 - SF) x RF

NOTES:
(a) Radionuclides shown with +D include daughter products in the risk calculations.
(b) Concentrations shown are the maximum surface soil, soil boring, or sediment sample concentration detected for each radionuclide.
(c) Dose factors from NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Dose".
(d) Cancer incidence risk factors taken from January, 1992 Health Effects Summary Tables (HEAST).

Table B-20 Ingestion of Contaminated Soils Standley Lake Diversion Project Intake and risk calculations for adult recreational receptor Upper bound (approximate RME) evaluation				
Samples SL#-Comp, SB#-Comp		Maximum constituent concentrations from composite surface soil, composite soil boring, or sediment samples		
Chemical	Soil Conc. (mg/kg)	Intake (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient intake/RfD
Manganese	1400.0	4.68E-04	0.1	0.004681
Nickel	30.0	1.00E-05	0.02	0.000502

Intake = CS x IR x CF x FI x EF x ED/BW x AT

exposure parameters

CS=		mg/kg	maximum soil conc. (CH2M Hill, 1992 field data)
IR=	120	mg soil/day	age adjusted ingestion rate (EPA, 1991a)
CF=	1.0E-06	kg/mg	soil conversion factor (EPA, 1989a)
FI=	1		fraction ingested (EPA, 1989a)
EF=	60	days/year	exposure frequency (CH2M Hill, 1993 Tech Memo)
ED=	24	year	exposure frequency (CH2M Hill, 1993 Tech Memo)
BW=	59	kg	age adjusted body weight (EPA, 1991a)
AT=	8760	days	averaging time noncarcinogenic effects (EPA, 1989a)
AT=	25550	days	averaging time carcinogenic effects (EPA, 1989a)

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TABLE B-21
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
INGESTION OF SOIL OR SEDIMENT
POST CONSTRUCTION RECREATIONAL MAXIMUM EXPOSURE SCENARIO

RADIONUCLIDE (a)	SAMPLE CONCENTRATION (pCi/g)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INGESTION DOSE CONVERSION FACTOR (b) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (c)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INGESTION (pCi)-1 (d)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER INCIDENCE
U-234	1.57	11.304	339.12	2.83E-04	3.20E-03	9.60E-02	1.60E-11	5.43E-09	3.4
U-235 +D	0.192	1.3824	41.472	2.66E-04	3.68E-04	1.10E-02	1.60E-11	6.64E-10	0.4
U-238 +D	1.49	10.728	321.84	2.55E-04	2.74E-03	8.21E-02	2.80E-11	9.01E-09	5.7
PU-239	0.718	5.1696	155.088	3.69E-04	1.91E-03	5.72E-02	2.30E-10	3.57E-08	22.5
AM-241	2.08	14.976	449.28	3.64E-03	5.45E-02	1.64E+00	2.40E-10	1.08E-07	68.0
TOTAL					6.27E-02	1.88E+00		1.6E-07	

EXPOSURE ASSUMPTIONS

Exposure scenario: Resident ingestion of contaminated soil or sediment	
Resident ingestion rate (g/day):	0.12
Exposure frequency (days/year):	60
Exposure duration (years):	30

NOTES:
(a) Radionuclides shown with +D include daughter products in risk calculations.
(b) Dose factors taken from Federal Guidance Report 11, "Limiting Values Of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion" (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.
(c) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).
(d) Cancer risk factors taken from January 1992 HEAST tables.

TABLE B-22
STANDLEY LAKE DIVERSION PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
EXPOSURE TO EXTERNAL RADIATION FROM CONTAMINATED SOIL OR SEDIMENT
RECREATIONAL (OUTDOOR) MAXIMUM EXPOSURE SCENARIO

RADIONUCLIDE (a)	SOIL CONCENTRATION (pCi/g)(b)	SURFACE DOSE CONVERSION FACTOR (c) (mrem-g/pCi-hr)	ANNUAL EFFECTIVE DOSE EQUIVALENT (mrem/yr)	TOTAL EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR EXT. EXPOSURE (d) (risk-g/pCi-y)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER RISK
U-234	1.57	5.70E-08	1.07E-05	3.22E-04	3.00E-11	2.02E-11	0.0
U-235 +D	0.192	3.80E-05	8.76E-04	2.63E-02	2.40E-07	1.97E-08	41.9
U-238 +D	1.49	7.50E-06	1.34E-03	4.02E-02	3.60E-08	2.30E-08	48.8
Pu-239	0.718	4.20E-08	3.62E-06	1.09E-04	1.70E-11	5.23E-12	0.0
Am-241	2.08	4.30E-06	1.07E-03	3.22E-02	4.90E-09	4.37E-09	9.3
TOTALS			3.30E-03	9.91E-02		4.71E-08	

EXPOSURE ASSUMPTIONS

Exposure scenario: Resident exposure to external radiation exposure from contaminated soil or sediment

Exposure Time (hr/day)	2
Exposure Frequency (days/year):	60
Exposure duration (years):	30
Shielding factor:	0
Fraction of year exposed:	0.01

NOTES:
(a) Radionuclides shown with +D include daughter products in the risk calculations.
(b) Concentrations shown are the maximum surface soil, soil boring, or sediment sample concentration detected for each radionuclide.
(c) Dose factors from NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Dose".
(d) Cancer incidence risk factors taken from January, 1992 Health Effects Summary Tables (HEAST).

Appendix C
Deposition Analysis Results

TABLE C-1
STANDLEY LAKE DIVERSION CANAL PROJECT
DEPOSITION ANALYSIS FOR CHEMICAL CONSTITUENTS

CHEMICAL	SAMPLE CONCENTRATION SURFACE SOIL MAXIMUM (ug/g)	SAMPLE CONCENTRATION SUBSURFACE SOIL MAXIMUM (ug/g)	SURFACE SOIL CONCENTRATION BY DEPOSITION (ug/g)
MANGANESE	384	742	1.62E+02
NICKEL	16.9	30	6.56E+00

SSC =((MSS*TDR*CF1+MSB*SDR*CF1)*CF2*CF3)/(D*SD)

DEPOSITION ASSUMPTIONS

SCC = Surface soil concentration by deposition (ug/g)	
MSS= Maximum surface soil constituent concentration (ug/g)	
MSB = Maximum subsurface soil constituent concentration (ug/g)	
TDR = Maximum topsoil dust deposition rate (ug/m2-s):	1.92
SDR = Maximum subsurface soil deposition rate (ug/m2-s):	98.2
SD = Soil density (g/cc):	1.43
D = Depth of deposition impact (cm):	1
CF1 = 1E-6 g/ug	1.00E-06
CF2 = 3.15E7 sec/yr	3.15E+07
CF3 = 1E-4 m2/cm2	1.00E-04

DEPANALY.WK1

Table C-2
Ingestion of Contaminated Soils or Sediments
Resulting from soil deposition
Standley Lake Diversion Project
Intake and risk calculations for adult resident receptor
Upper Bound (approximate RME) evaluation
Lifetime exposure

Samples SL#-Comp, SB#-Comp, SD#		Maximum constituent concentration from composite surface soil samples and composite soil boring samples used to estimate concentrations resulting from soil deposition				
Chemical	Soil Conc. (mg/kg)	Intake (mg/kg-day)	SF (kg-day/mg)	RfD (mg/kg-day)	ILCR intake*SF	Hazard Quotient intake/RfD
Manganese	162.0	2.66E-04		0.1		0.002663
Nickel	6.6	1.08E-05		0.02		0.000539

Intake = CS x IR x CF x FI x EF x ED/BW x AT

exposure parameters

CS=		mg/kg	maximum soil conc. (CH2M Hill, 1992 field data)
IR=	120	mg soil/day	ingestion rate (EPA, 1991)
CF=	1.0E-06	kg/mg	soil conversion factor (EPA, 1989)
FI=	1		fraction ingested (EPA, 1989)
EF=	350	days/year	exposure frequency (CH2M Hill, 1993 Tech Memo)
ED=	30	year	exposure frequency (CH2M Hill, 1993 Tech Memo)
BW=	70	kg	body weight (EPA, 1991)
AT=	10950	days	averaging time noncarcinogenic effects (EPA, 1989)
AT=	25550	days	averaging time carcinogenic effects (EPA, 1989)

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TABLE C-3
STANDLEY LAKE DIVERSION CANAL PROJECT
DEPOSITION ANALYSIS FOR RADIONUCLIDES

RADIONUCLIDE	SAMPLE CONCENTRATION		SURFACE SOIL CONCENTRATION BY DEPOSITION (pCi/g)
	SURFACE SOIL MAXIMUM	SUBSURFACE SOIL MAXIMUM	
U-234	1.51	1.57	3.5E-01
U-235 +D	0.192	0.127	2.8E-02
U-238 +D	1.31	1.39	3.1E-01
PU-239	0.718	0.041	1.2E-02
AM-241	2.08	0.0318	1.6E-02

EXPOSURE ASSUMPTIONS

TDR = Maximum topsoil dust deposition rate (ug/m2-s):	1.92
SDR = Maximum subsurface soil deposition rate (ug/m2-s):	98.2
SD = Soil density (g/cc):	1.43
D = Depth of deposition impact (cm):	1
CF1 = 1E-6 g/ug	1.00E-06
CF2 = 3.15E7 sec/yr	3.15E+07
CF3 = 1E-4 m2/cm2	1.00E-04

SSC =((MSS*TDR*CF1+MSB*SDR*CF1)*CF2)/(D*SD)

DEPANALY.WK1

TABLE C-4
STANDLEY LAKE DIVERSION CANAL PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
INGESTION OF DEPOSITED SOIL OR SEDIMENT (INCREMENTAL RISK)
RESIDENTIAL MAXIMUM EXPOSURE SCENARIO

RADIONUCLIDE (a)	SAMPLE CONCENTRATION (pCi/g) (b)	ANNUAL INTAKE (pCi/yr)	TOTAL INTAKE (pCi)	INGESTION DOSE CONVERSION FACTOR (c) (mrem/pCi)	COMMITTED EFFECTIVE DOSE EQUIVALENT 1 YR INTAKE (mrem/yr) (d)	TOTAL COMMITTED EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR INGESTION (pCi)-1 (e)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER INCIDENCE
U-234	0.35	14.7	441	2.83E-04	4.16E-03	1.25E-01	1.60E-11	7.06E-09	26.3
U-235 +D	0.028	1.176	35.28	2.66E-04	3.13E-04	9.38E-03	1.60E-11	5.64E-10	2.1
U-238 +D	0.31	13.02	390.6	2.55E-04	3.32E-03	9.96E-02	2.80E-11	1.09E-08	40.7
PU-239	0.012	0.504	15.12	3.69E-04	1.86E-04	5.58E-03	2.30E-10	3.48E-09	12.9
AM-241	0.016	0.672	20.16	3.64E-03	2.45E-03	7.34E-02	2.40E-10	4.84E-09	18.0
TOTAL					1.04E-02	3.13E-01		2.7E-08	

EXPOSURE ASSUMPTIONS

Exposure scenario: Residential (child to adult) ingestion of contaminated soils from deposition
Resident ingestion rate (g/day): 0.12
Exposure frequency (days/year): 350
Exposure duration (years): 30

NOTES:
(a) Radionuclides shown with +D include daughter products in risk calculations.
(b) Concentrations were calculated based on the assumption that deposited soils (dust) originate from soils containing the maximum contaminant concentrations detected in surface soils, sediments, or soil borings.
(c) Dose factors taken from Federal Guidance Report 11, "Limiting Values Of Radionuclide Intake and Air Concentration and Dose Factors for Inhalation, Submersion, and Ingestion" (EPA-520/1-88-020). Dose factors include the contribution to dose from ingrowth of decay products after intake of parent radionuclide.
(d) Committed effective dose equivalent expressed as committed (50 yr.) dose (mrem) due to one year of exposure (mrem/yr).
(e) Cancer risk factors taken from January 1992 HEAST tables.

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TABLE C-5
STANDLEY LAKE DIVERSION CANAL PROJECT
EXCESS LIFETIME RISK OF CANCER INCIDENCE
EXPOSURE TO EXTERNAL RADIATION FROM DEPOSITION OF CONTAMINATED SOIL OR SEDIMENT
RESIDENTIAL MAXIMUM EXPOSURE SCENARIO

RADIONUCLIDE (a)	SOIL CONCENTRATION (pCi/g)(b)	SURFACE DOSE CONVERSION FACTOR (c) (mrem-g/pCi-hr)	ANNUAL EFFECTIVE DOSE EQUIVALENT (mrem/yr)	TOTAL EFFECTIVE DOSE EQUIVALENT (mrem)	CANCER INCIDENCE RISK FACTOR FOR EXT. EXPOSURE (d) (risk-g/pCi-y)	RISK OF CANCER INCIDENCE	PERCENT OF CANCER RISK
U-234	0.35	5.70E-08	1.68E-04	5.03E-03	3.00E-11	2.52E-10	0.1
U-235 +D	0.028	3.80E-05	8.94E-03	2.68E-01	2.40E-07	1.61E-07	37.4
U-238 +D	0.31	7.50E-06	1.95E-02	5.86E-01	3.60E-08	2.68E-07	62.1
Pu-239	0.012	4.20E-08	4.23E-06	1.27E-04	1.70E-11	4.90E-12	0.0
Am-241	0.016	4.30E-06	5.78E-04	1.73E-02	4.90E-09	1.88E-09	0.4
TOTALS			2.92E-02	8.77E-01		4.31E-07	

EXPOSURE ASSUMPTIONS

Exposure scenario: Residential exposure to external radiation from contaminated soils caused by deposition

Exposure Time (hr/day)	24
Exposure Frequency (days/year):	350
Exposure duration (years):	30
Shielding factor:	0.2
Fraction of year exposed:	1

NOTES:
(a) Radionuclides shown with +D include daughter products in the risk calculations.
(b) Concentrations were calculated based on the assumption that deposited soils (dust) originate from soils containing the maximum contaminant concnetrations detected in surface soils, sediments, or soil borings.
(b) Dose factors from NUREG/CR-5512 "Residual Radioactive Contamination from Decommissioning, Technical Basis for Translating Contamination Levels to Annual Dose".
(c) Cancer incidence risk factors taken from January, 1992 Health Effects Summary Tables (HEAST).

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TABLE C-6
FUGITIVE DUST DEPOSITION RATES FROM TOPSOIL & SUBSURFACE SOI

RESIDENTIAL RECEPTORS X(ft)	Y(ft)	RECP ID#	top dust (ug/m^2/sec)	sub dust (ug/m^2/sec)	TOTAL (ug/m^2/sec)
26024	49907	1	0.25910	3.05916	3.31826
30002	51578	2	0.32532	18.82030	19.14562
30319	51347	3	0.19556	10.45477	10.65033
30529	50683	4	0.11363	4.86904	4.98267
30623	50884	5	0.12355	5.66508	5.78863
30743	51244	6	0.15917	8.29913	8.45830
30743	52324	7	0.49211	30.76569	31.25780
35647	51702	8	0.19626	8.55003	8.74629
36048	52119	9	0.59767	28.78312	29.38079
36030	52238	10	1.91765	96.28513	98.20278
36369	52647	11	0.50088	23.68090	24.18178
38142	52540	12	0.39079	13.56046	13.95125
41549	51242	13	0.43200	8.41989	8.85189
42766	48966	14	0.73280	14.07709	14.80989
42779	50112	15	0.44313	8.56970	9.01283
27600	49460	20	0.40643	4.83225	5.23868
30580	52600	34	0.28866	17.18025	17.46891
30940	52590	35	0.32124	19.54138	19.86262
31310	52580	38	0.45818	28.69795	29.15613
31670	52580	40	0.57568	36.45308	37.02876
32020	52580	42	0.58326	36.81606	37.39932
32380	52580	44	0.58598	36.54730	37.13328
32750	52580	46	0.59507	35.50924	36.10431
33110	52570	48	0.61953	31.77568	32.39521
33470	52570	51	0.61165	30.69724	31.30889
33830	52560	53	0.62515	31.22794	31.85309
34180	52560	55	0.61578	30.61691	31.23269
34550	52560	57	0.61621	30.52125	31.13746
34910	52550	59	0.64940	32.09649	32.74589
35270	52560	61	0.63530	31.23579	31.87109
35630	52560	64	0.64522	31.56847	32.21369
35990	52560	66	0.65032	31.61386	32.26418
36350	52560	68	0.65462	31.53349	32.18811
36720	52550	70	0.67436	32.11916	32.79352
37070	52550	73	0.66693	31.28591	31.95284
37420	52550	75	0.64681	29.51851	30.16532
37780	52550	77	0.49940	20.87068	21.37008
38500	52560	82	0.39005	9.80085	10.19090
38890	52550	84	0.52444	11.01836	11.54280
39350	52550	86	0.56983	11.43697	12.00680
39750	52550	89	0.61004	12.04318	12.65322
40080	52540	91	0.51069	10.07576	10.58645
40620	52540	95	0.38611	7.62220	8.00831
40880	52540	96	0.36563	7.20449	7.57012
41740	52530	97	0.20182	4.01874	4.22056
41750	50900	98	0.47573	9.24203	9.71776
42380	50580	103	0.47790	9.24954	9.72744
42540	50310	104	0.54639	10.54767	11.09406

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